RAVENSTONES AND GREENFIELD VALLEY.

To face p. 1]

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

MEMOIRS OF THE GEOLOGICAL SURVEY ENGLAND AND WALES

EXPLANATION OF SHEET 86 New Series

The Geology of the Country around Holmfirth and Glossop

By

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PREFACE

The area shown on the one-inch New Series map, Sheet 86 (Glossop) and described in this memoir was originally surveyed on the six-inch scale by A. H. Green, E. Hull, J. R. Dakyns and J. C. Ward. The Old Series one-inch maps, Sheets 81 N.W., N.E. and 88 S.W., S.E., were published at various dates from 1852 to 1864 and the original six-inch maps between 1863 and 1875. The accompanying memoirs are all out of print but the greater part of the area is briefly described in A. H. Green's 'Geology of the Yorkshire Coalfield' (1878).

The re-survey was begun in 1926 by Dr. D. A. Wray, Mr. J. V. Stephens, Mr. Wilfrid Edwards and, for a short period only, Mr. G. V. Wilson, under Mr. C. E. N. Bromehead as District Geologist. A small area along the western border was mapped by Mr. W. Lloyd, then a member of the staff at Manchester. From the list of six-inch maps given on p. vii of this memoir the part taken by each member of the staff can be understood, the largest area falling to Mr. Edwards.

For the memoir each officer has supplied notes on the area he surveyed. Mr. Edwards put together the chapter on the Millstone Grits up to the Huddersfield White Rock and most of that on Geological Structure; Dr. Wray the greater part of those on the Coal Measures and that on Palaeontology; Mr. Stephens that on the Glacial and Recent Deposits; Mr. Bromehead has written the remainder and edited the whole.

The fossils have been identified in the Palaeontological Department, but much assistance has been received from Prof. A. E. Trueman in the work on the freshwater lamellibranchs, from Mr. W. S. Bisat on the goniatites and from Dr. J. W. Jackson on the marine lamellibranchs.

Our thanks are also due to the colliery companies, notably Messrs. Stringer and Son of Clayton West, and to the many firms working building-stone, fireclay, ganister, etc., who have all afforded useful information and given us every facility for examining pits and quarries.

A comparison of the New Series with the Old Series maps will show that our knowledge of the Millstone Grits has been enormously increased since the first survey of the district, and that this, together with certain alterations in the mapping of the Coal Measures, has done much to elucidate the structure of the area.

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6th October, 1932.

CONTENTS

ILLUSTRATIONS

TEXT-FIGURES

PLATES

EXPLANATION OF PLATES

PLATE I.—Frontispiece.—Ravenstones and Greenfield Valley. An isolated stack of Kinderscout Grit showing characteristic weathering. Crags of the same rock can be seen just below the skyline. The reservoir is mostly on Grindslow Shales, exposed to the left of the dam. The observer is facing north-west.

PLATE II.—A. Black Clough, with base of Kinderscout Grit. The stream is cascading over the uppermost beds of the Grindslow Shales, with the overlying Kinderscout Grit forming crags in the left bank. Alluvial boulders in the foreground. The vegetation is typical of the more sheltered ground in the cloughs. The observer is facing south-west.

B. Natural bridge of Kinderscout Grit, Marsden Clough, Holmbridge. Beneath the massive grit, well seen on the left, is a bed of shale. The deepening by pot-hole action of a rock-pool in the grit has enabled the stream to reach the shale and undermine the sill of the pool, which is left to form the bridge. The observer is facing west.

PLATE III.—A. Outcrops of Middle Grits, Ramsden Clough. The top of the hill, Elbow End, is formed of Huddersfield White Rock. On the slope of the hill, on the left of the photograph, a thin sandstone lying just below the mut. γ marine band crops at Mould Scar. Separated from this by about 50 ft. of shales is a thick sandstone seen in the middle distance and in the foreground; below this rock is more shale with the mut. β marine band at the base.

B. Pule Hill, Marsden. The hill is capped by an outlier of Pule Hill Grit, the most constant member of the Middle Grits Series. The long slope on the left consists of shale; the bare patch is an exposure of shaly mudstone containing two marine bands about 30 ft. apart, characterized by *Reticuloceras reticulatum* late mut. α and early mut. β respectively. The position of these has been indicated on the Plate. The foreground is the dip-slope of the top of the Kinderscout Grit.

PLATE IV.—A. Cheese Gate Nab, Hepworth—a part of the escarpment of the Lower Coal Measures. The prominent hill, Cheese Gate Nab, is capped by Greenmoor Rock. The view is taken from Foster Place on the Huddersfield-Dunford road at a height of 825 ft. O. D., approximately on the outcrop of the Middle Bed Coal. The summit of the hill is 1,250 ft. above O. D. The intermediate platform prominent on the left is formed by the Upper Band Rock.

B. The River Don, about half a mile below Penistone. The sandstone exposed in the bank is a part of the Penistone Flag Series. The narrow pack-horse bridge lies on the route over the moors from Derbyshire and Cheshire, formerly much used for the conveyance of lime, salt and other goods by means of pack-horses.

PLATE V.—See page 158.

LIST OF SIX-INCH MAPS

The following is a list of the revised six-inch geological maps included in the one-inch map, Sheet 86, with the initials of the surveyors and dates of survey. The names of the officers are as follows :—C. N. Bromehead, Wilfrid Edwards, W. Lloyd, J. V. Stephens, G. V. Wilson and D. A. Wray. All those maps which include an appreciable area of Coal Measures have been published, and are marked with an asterisk. The remainder are available for public reference only in MS. form at the head office of the Geological Survey. Copies of these MS. maps can be supplied at the cost of drawing and colouring.

These six-inch maps show features such as shafts, adits and boreholes, as well as sites and details of geological sections, minor geological divisions, and other important information which cannot be inserted on the one-inch map. The published maps, also, usually display a generalized vertical section of the Coal Measures.

Yorkshire

	258	N.E.	Bleakedgate Moor	D.A.W.	1921
		S.E.	Denshaw	D.A.W. & W.L.	1928
	259	N.W.	Buckstones Moss	D.A.W.	1925
		N.E.	Slaithwaite	D.A.W.	1925
		S.W.	Standedge	D.A.W.	1928
		S.E.	Marsden	D.A.W.	1928
	260	N.W.	Linthwaite	D.A.W.	1925
*		N.E.	Almondbury	D.A.W.	1925
		S.W.	Meltham	D.A.W.	1928
*		S.E.	Brock Holes	D.A.W.	1928
*	261	N.W.	Kirkburton	D.A.W.	1925
*		N.E.	Flockton	D.A.W.	1925
*		S.W.	Shelley	D.A.W.	1928
*		S.E.	Clayton West	D.A.W.	1928
	271	N.W.	Saddleworth	W.E.	1928
		N.E.	Wessenden Moor	W.E.	1928
		S.W.	Greenfield	W.E.	1928
		S.E.	Middle Edge Moss	W.E.	1928
	272	N.W.	Holmbridge	C.N.B.	1926, 1927
*		N.E.	Holmfirth	C.N.B.	1926, 1927
		S.W.	Holme Moss	C.N.B. & G.V.W.	1926
*		S.E.	Scholes	G.V.W.	1926
*	273	N.W.	Birds Edge	C.N.B.	1927
*		N.E.	Gunthwaite	C.N.B.	1927, 1928
*		S.W.	Thurlstone	G.V.W.	1927
*		S.E.	Hoyland Swaine	G.V.W. & C.N.B.	1927, 1928
	279	N.W.	Swineshaw Moor	W.E.	1927
		N.E.	Bareholme Moss	W.E.	1927
	280	N.W.	Withens Moor	G.V.W. & W.E.	1928
		N.E.	Dunford Bridge	G.V.W.	1927
		S.E.	Howden Moors	W.E. & G.V.W.	1927, 1928
*	281	N.W.	Langsett	G.V.W.	1927
*		N.E.	Oxspring	G.V.W. & C.N.B.	1927, 1930
		S.W.	Midhope Moors	W.E.	1928
*		S.E.	Stocksbridge	W.E. & J.V.S.	1928, 1930
	286A	N.E.	Ronksley Moor	J.V.S.	1928
	287	N.W.	Broomhead Moor	J.V.S.	1928
		N.E.	Wightwizzle	W.E. & J.V.S.	1929

LIST OF SIX-INCH MAPS (*continued*)

Lancashire

* 89	N.E.	Bleakedgate Moor	D.A.W.	1921, 1928
*	S.E.	Crompton Moor & Delph	W.L., D.A.W. & W.E.	1926, 1928
* 97	N.E.	Austerlands	W.L. & W.E.	1926, 1928
*	S.E.	Mossley	W.L. & W.E.	1925, 1928
*105	N.E.	Stalybridge	W.L. & W.E.	1924, 1925, 1928
*	S.E.	Dukinfield	W.L. & J.V.S.	1925, 1926
112	N.E.	Hyde	W.L. & J.V.S.	1925, 1926

Cheshire

3	N.E.	Buckton Vale	W. E. & W. L.	1925, 1928
	S.E.	Hollingworth Hall	W. E. & W.L.	1925, 1928
4	N.W.	Laddow Moss	W.E.	1927
	N.E.	Woodhead	W.E.	1927
	S.W.	Peaknaze Moor	W.E.	1926
11	N.E.	Broadbottom	W.L. & J.V.S.	1925, 1926

Derbyshire

1	S.W.	Crowden	W.E.	1926
	S.E.	Salter's Brook	W.E.	1928
2	N.E.	Hadfield	W.E.	1926
	S.W.	Hattersley	W.L. & J.V.S.	1929
*	S.E.	Glossop	J.V.S.	1926
3	N.W.	Torside	W.E.	1926
	N.E.	Bleaklow Hill	W.E.	1928
	S.W.	Doctor's Gate	J.V.S.	1926, 1929
	S.E.	Alport Moor	J.V.S.	1929

THE GEOLOGY OF THE COUNTRY AROUND HOLMFIRTH AND GLOSSOP

CHAPTER I

INTRODUCTION

The area represented on Sheet 86 and described in the present memoir includes parts of four counties, the West Riding of Yorkshire, Lancashire, Cheshire and Derbyshire, and is drained by tributaries of the Ouse, Mersey and Trent. The boundaries both of the natural division into river-basins and of the civil division into counties are somewhat anomalous. The primary watershed between the North Sea and the Irish Sea enters the area from the north about a mile and a half from the western margin and runs south-east to Black Hill (1,908 ft. above O.D.), Wike Head and Featherbed Moss; from the north it is followed by a parish boundary (and therefore shown on the map) as far as Wessenden Head Moor, and from Black Hill to Wike Head by the county boundary between Yorkshire and Cheshire. From Wike Head to Featherbed Moss the watershed runs in a gentle curve, not coinciding with any boundary shown on the map, but then bends westward and is followed by a parish boundary past Swains Head, where it crosses the Yorkshire-Derbyshire boundary at right angles, to Bleaklow Head (2,061 ft. above O.D.). Here it turns sharply south and takes an irregular course, shown by the parish boundary, to Devil's Dike, where it passes out of the area and goes south-west to Ashop Head.

On the western side of this line the drainage is to the Mersey by the rivers Tame and Etherow; the basin of the latter forms a salient projecting some seven miles east of the general run of the North Sea—Irish Sea divide (see map, Fig. 1). To the east the drainage is to rivers entering the Humber; the Marsden Brook and the Holme with their tributaries join the Calder; the Dearne, Little Don and Ewden Beck all join the Don, of which the main stream rises around Dunford Bridge and flows through Penistone. A small area on the south is drained by the Derwent and its tributaries and so forms part of the basin of the Trent. The boundary between this river and the Etherow from Featherbed Moss to Devil's Dike is given above; between it and the Don the line runs from Featherbed Moss to Howden Edge, Rocking Stones, Margery Hill and another Featherbed Moss (see below) near the southern margin of the area.

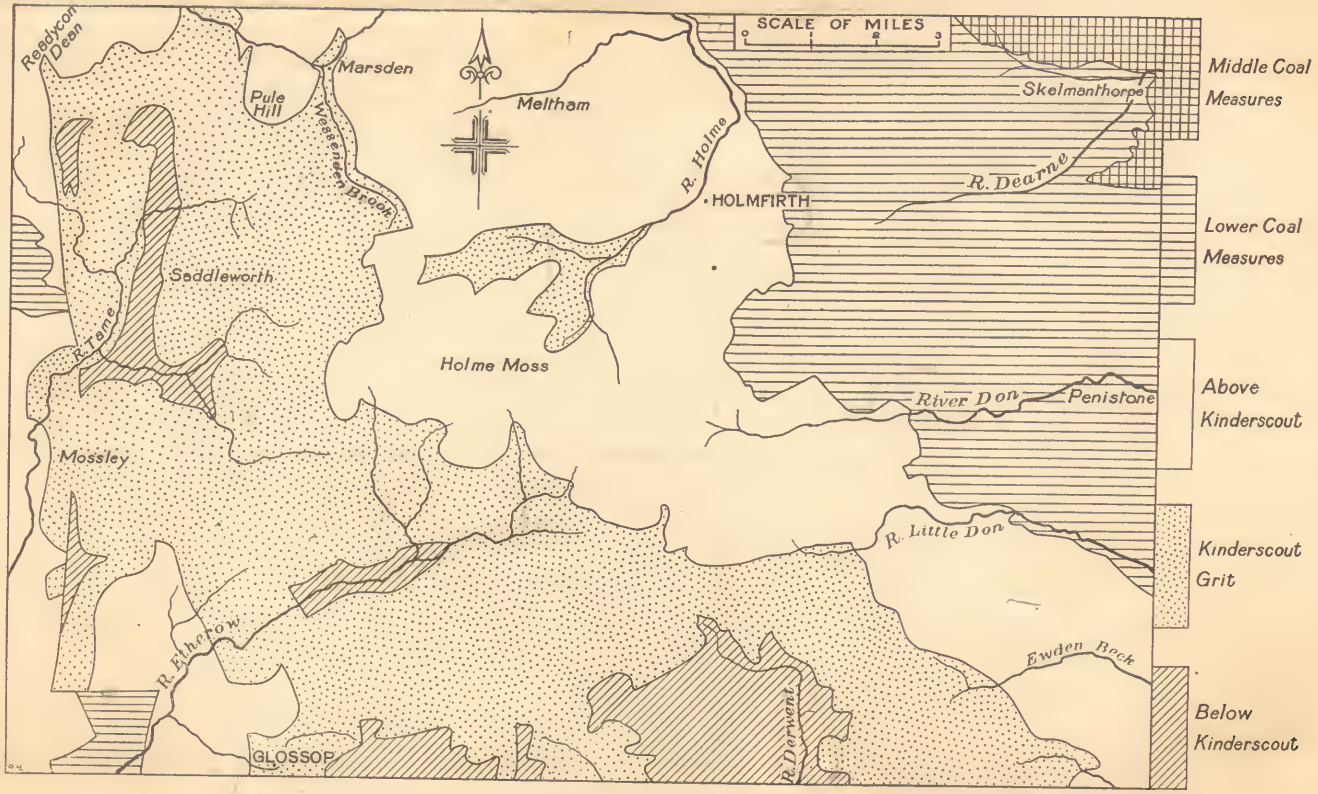

FIG. 1.—*Sketch-map of the geology of the Holmfirth and Glossop area.*

Yorkshire (West Riding) covers the whole of the area draining to the Ouse, but also extends westwards beyond the margin of the map. A tiny corner of Lancashire is cut off at the north-west, south of which Yorkshire continues southwards to between Greenfield and Mossley; here the boundary with Lancashire enters from the west, crosses the River Tame at right angles and, ascending the left bank, follows the southern margin of the basin of the Greenfield Brook. Near Ormes Moor Lancashire gives place to Cheshire, and the boundary of that county with Yorkshire continues, through yet another Featherbed Moss, to Black Hill and along the Pennine watershed. From Wike Head it descends to the Salter's Brook, the headwaters of the Etherow. Where the Yorkshire boundary leaves it to ascend to Swains Head the river becomes the boundary between Cheshire and Derbyshire, which follows it till it leaves the area shown on the map. From Swains Head the Yorkshire-Derbyshire boundary descends to the River Derwent, which it then follows. Thus Yorkshire, in addition to the area draining to the Ouse, includes the upper basin of the Tame, a small part of that of the Etherow and the left bank of the Derwent. The Cheshire-Lancashire boundary follows no natural feature: from Ormes Moor it descends the Ogden Brook for a short distance, crosses to the valley of the Swineshaw Brook, turns north over the moor to Bucktonvale, descends to the River Tame, just south of Mossley, follows that river for half a mile and turns west to pass out of the area.

The dominant feature of the district is the high moorland which here composes the 'Pennine Range'; it rises to heights of 1,450 ft. in the north and over 2,000 ft. in the south. Between Marsden and Diggle in the north the moors barely exceed two miles in width, but south-eastwards the width increases rapidly up to twelve miles along the southern margin of the area. This stretch is, however, interrupted by the valley of the Etherow, known as Longdendale; the interruption is not great, despite the depth of the valley, as the banks maintain a moorland character almost to water-level. The Derwent valley forms a depression in the south-east, but the river and its tributaries remain typical moorland streams for some distance beyond our boundary.

This great tract of country is everywhere formed by the Millstone Grits, that is to say by a long succession of grits and sandstones alternating with soft shales and mudstones. The most massive part of the Millstone Grit sequence is the Kinderscout Grit series, which almost everywhere occupies the highest ground (see Fig. 1). The lower beds are found as inliers in the basins of the Tame, Etherow and Derwent, and to the east of Glossop. Those above the Kinderscout Grits occupy a belt of ground striking south-eastwards from between Marsden and the valley of the Holme, broken, however, by an inlier of Kinderscout Grits in the Upper Holme valley. On the west the beds, on account of the

position and asymmetrical character of the main axis (see Chapter V) occupy only small and irregular areas.

Throughout the Millstone Grits the harder rocks tend to form level or gently sloping surfaces, according to the dip (see Plate IIIB). In many cases these plateaux terminate in lines of wild crags or groups of isolated stacks called ' Edges,' ' Stones ' or ' Rocks ' (see frontispiece), all testifying to prolonged exposure to wind and rain. The more massive and closely cemented beds of the grits stand out prominently, and in some cases the undercutting of the less durable beds has resulted in the formation of ' Rocking Stones,' as for instance those shown on the map overlooking the left bank of the Derwent, though several of these have been displaced in recent years. The softer shales and mudstones form concave slopes, often marshy, between successive grit plateaux, locally known as ' slacks.'

Apart from the exposures of bare rock mentioned above the moors are largely covered with peat, up to 8 ft. in thickness, consisting mainly of cotton-grass (*Eriophorum*) which flourishes exceedingly on the ill-drained ground, almost to the exclusion of sphagnum mosses. Locally, however, these cotton-grass areas are termed ' mosses '; the name ' Featherbed Moss ' which, as noted above, occurs three times on the one-inch map is an allusion to the appearance when the cotton-grass is in fruit. Another characteristic plant of these damp areas is the cloudberry, from the Danish term for which the name Meltham is, perhaps, derived.[1] Heather flourishes only on the better drained slopes and clough sides where it is accompanied by bilberry, cranberry, bracken, etc., the names Cranberry Clough, Bilberry Clough and Wimberry Moss allude to these plants. On less elevated ground the prevalent grass gives rise to such names as Good Bent, near Holme.

Coal Measures are found on both sides of the central outcrop of the Millstone Grits, but, owing to the steep westerly dips on the west and the gentle east-north-east dip on the east, the two areas are of very different character and extent (Fig. 1). On the west the areas occupied by Coal Measures south-west of Delph and around Mottram are almost negligible in size, but the structure is brought out by the outcrops of the Rough Rock, the uppermost member of the Millstone Grits, which is coloured reddish-brown on the map. At Stalybridge this outcrop is within three-quarters of a mile of that of the Shale Grit which underlies the Kinderscout Grits. On the east the minimum figure for this distance is about three miles. On this side the Coal Measures occupy some fifty square miles, or about a quarter of the area shown on the map. In general outline the ground is not unlike that of the Millstone Grits in that the several sandstones form a series of dip-slopes with intervening scarps; but the proportion of sandstones to shales, the elevation and the rainfall are all less. Consequently this country is much less wild than that of the central uplands. Natural

[1] Goodall, A., ' Place Names of South-West Yorkshire,' *Cambridge*, 1914.

exposures of bare rock seldom occur on the scarps; the dip-slopes are usually grassy, when they are referred to as commons in the local place names: sometimes a heather association is found, when the term 'moor' is used in distinction from the wet cotton-grass 'mosses.'[1] Trees are a prominent feature of the landscape; "the oak, ash, elm and sycamore flourish abundantly. Such a profusion of vegetation is not found on the Lancashire side of the Pennine Chain, where trees are rarely found except in sheltered places."[2] The valleys of the Coal Measures country, the Dearne through Denby Dale, the Don below Hazlehead and their tributary streams are well wooded, in contrast with the wild defiles, sheltering occasional thorns, birches and mountain ash, known as 'cloughs' in the Millstone Grit country. The contrast is well seen on comparing Plates I, II and III with Plate IV. The streams rising in the moors are subject to remarkable changes of volume according to the weather: W. Watts states that the Little Don at Langsett in seasons of drought is reduced in volume of flow to ·028 cubic feet per second per 100 acres drained, and swells out in time of maximum flood to 30 cubic feet per 100 acres, a rise of nearly 1,100 per cent. (*op. cit.*, p. 264). The high rainfall on the moors, over 50 in. per annum, is the main cause. The difference on the lower ground of the Coal Measures, where the prevalent westerly winds have already dropped the main part of their burden in crossing the Pennines, is a remarkable feature. At Woodhead the yearly average rainfall is 50·18 in., but at Ingbirchworth, less than eight miles distant, 38·89.[3]

On the whole, the district is sparsely inhabited, the population being mainly concentrated in the valleys converging towards Huddersfield and in that of the Tame, sparse on the uplands and practically absent on the high moors. It is a noteworthy point that in ancient times the relative proportions were reversed; this proportion held from the earliest human settlements (see pp. 136, 137) to the end of the Roman occupation. The change came with startling suddenness when the 'Saxon' group of nationalities arrived. The contrast is well brought out for our area by the maps of the Huddersfield Museum Handbooks, Nos. 2, 3 and 4. These show the district in the times of early man, of the Romans and of the Angles, Danes and Norse respectively. The change appears to be due to the fact that the earlier inhabitants required open country, however poor the soil, whereas the Saxon peoples were accustomed to living in forest clearings and settled in the thickly wooded lowlands.[4] The contrast has to some extent been deliberately increased in recent years; the corporations owning large reservoirs endeavour to avoid contamination in the gathering

[1] Woodhead, T. W., 'The Scenery of Huddersfield and its Significance,' *Huddersfield*, 1923, p. 14.
[2] Watts, W., 'Excursion to Langsett,' *Trans. Manchester Geol. Soc.*, vol. xxvi, 1901, p. 263.
[3] Moss, C. E., 'Vegetation of the Peak District,' *Cambridge*, 1913.
[4] See R. G. Collingwood, 'Town and Country in Roman Britain,' *Antiquity*, vol. iii, 1929, pp. 261-276.

grounds by reducing the number of possible sources, and many of the dwellings on their property are now derelict.

The district was, and to some extent still is, more or less isolated. There is no easy route through the Pennines comparable with the valley of the Calder or the Skipton-Clitheroe gaps to the north. The two east and west railway routes traversing it both involve tunnels of three miles or over, and the great north and south routes lie outside it on either side. To this isolation Mr. Walter Haigh has attributed the many archaic characteristics which the local dialect still retains.[1] For many centuries all traffic was carried by pack-horse, and many relics of this method still exist. There is a considerable number of the typical narrow pack-horse bridges, of which one near Penistone is shown in Plate IVB; another fine example is in Red Brook Clough, one and a half miles west of Marsden, where the paved way can be seen. Many of the routes can be traced by the sunken ways over the lower ground, or by moorland paths such as Cut Gate, connecting the Derwent valley with Langsett, or Doctor's Gate east of Glossop.[2] A fine sunken way, paved with the original stones, much worn, can be seen between the Hall and the Dam at Gunthwaite. The name 'Jagger Lane' from jagger, a pedlar or pack-horse driver, occurs several times in the district. Along these ways were carried such commodities as salt from Cheshire, remembered in the name Salter's Brook, lime from Derbyshire and the local woollen products (see below). A slight increase in the facilities of transport is indicated in the name Dunford Bridge, written 'Dunneford' in 1282, meaning the ford, later replaced by a bridge, over the Don.[3]

Industries

The industries that can be regarded as indigenous to the area are not of great importance. To the north lies the woollen district of Yorkshire, to the west the cotton district of Lancashire; the outskirts of both penetrate the valleys and account for a large proportion of the industrial activity within our boundaries. Similarly, it is only the outer margins of the Yorkshire and of the Lancashire-Cheshire coalfields that are covered by the map; the amount of coal now produced is much less than even local requirements.

Stone quarrying is more important; large quarries working the Rough Rock and the Greenmoor Rock send, or have sent, their products to distant parts of the country; fireclay goods and ganister are also sent out of the district (see Chapter VIII).

[1] 'The Dialect of the Huddersfield District,' Oxford Press, 1928.

[2] 'Gate' is the old Yorkshire term for a road or street, cf. the street names in York and other towns.

[3] For place names in general see A. Goodall, *op. cit.*; for pack-horse routes cf. W. B. Crump, 'Ancient Highways of the Parish of Halifax,' *Journ. Halifax Antiq. Soc.*, 9 parts, 1924 to 1929. A similar account of those in this area is in preparation by the same author for the Huddersfield Museum.

Agriculture and Soils

Throughout the whole area the soils are characterized by their poverty in lime, which greatly restricts the agricultural possibilities. The only natural sources of lime are the occasional bullions in some of the marine bands in the Millstone Grits and above the Halifax Hard Bed Coal. Mr. W. H. Burrell informs us of the discovery in Rake Dike, near Holme, of a moss, *Hypnum commutatum* and a liverwort, *Pellia fabbroniana,* both calciphil species, and we were at once able to identify the exact localities as the outcrop of the mut. β marine band (see p. 51); the water trickling from this spot showed a hardness, in a field test, of 9 to 10 degrees, whereas the normal stream water of the district gives 3 to 4 or less. The acidity of the soil is increased by the smokiness of the atmosphere. Liberal treatment with lime is therefore essential, both on the Millstone Grits and on the Coal Measures. The nearest sources of lime are the Carboniferous Limestone of Derbyshire and the Magnesian Limestone of east Yorkshire. Lime was formerly brought thence by pack-horse. At the time of the resurvey little liming was done, but during the last two or three years has been more frequent, presumably because of the convenience of transport by motor lorry from kiln to field.

On account of the poverty of the soils sheep raising has always been of more importance than arable farming. In former times all holdings were small and nearly every household wove its own wool on hand looms; the weavers' houses, with windows occupying almost the entire length of the walls, are a typical feature in the older villages.[1] Such work passed in turn to mills worked by the rapidly flowing streams and to those in the main valleys dependent on coal for their power. The industry now gains from the absence of lime, in that the local water supplies are soft and well fitted for cleaning and dyeing processes. The dependence upon sheep is reflected in the prevalence of such place names as Shepley, Shipley, Shibden, Ramsden, etc. The original woollen goods were mostly coarse, in fact Penistone gives its name to a coarse frieze, or woollen cloth with a nap on one side.

Small crops of hay and oats were raised, sufficient to make the farms self-supporting, but not in any quantity for sale. Recently poultry-farming, making no demand on the quality of the soil, has become important, as also has dairy-farming, the neighbouring industrial areas affording a ready market.

On the moorlands some attemps at afforestation have been made in the catchment areas of many of the reservoirs, but the smokiness of the atmosphere is a serious drawback; considerable success has been met with in the Derwent valley, but the plantations are mostly south of the boundary of the Glossop map. Grouse-shooting on the moors has now become largely a 'commercial proposition.'

[1] For a fine example see Huddersfield Museum Publications, no 1, 1921, fig. 9.

The soils of the Coal Measures are on the whole better than those of the Millstone Grits, though they suffer from the same lack of lime. The shales often give a heavy clay soil, which is mostly under grass, but the sandstones give lighter loams. Wheat, oats and potatoes are perhaps the most satisfactory arable crops; swedes and turnips are apt to suffer from 'finger and toe' disease, unless liming is liberal.[1] The Coal Measures are better wooded than the Millstone Grits, oak and elm being prevalent instead of birch, and the fields are often divided by hedgerows, in contrast with the dry stone walls of the Grits. On the latter the older buildings are of local gritstone, roofed with the more fissile flagstones; on the former fine examples of timber construction may sometimes be seen, the barn at Gunthwaite being famous. Present-day construction of brick, concrete, asbestos, etc., though possibly necessary for economic reasons, is apt to produce eyesores, though it has been pointed out that these can largely be avoided by a suitable choice of colours.[2]

Table of Formations

The following table summarizes the geological formations and their subdivisions which are represented on the map. The thicknesses are generalized from data collected in various parts of the area. On the map the shales and sandstones of the Lower and Middle Coal Measures are distinguished by colour, and the more important sandstones and coals are individually indicated by letters. In the Millstone Grits the shales are coloured uniformly throughout, but the grits and sandstones are shown by four colours for the main groups, *viz.*, *The* Rough Rock Series, the Middle Grits, the Kinderscout Grits and the Shale Grit. These again are individually distinguished by letters.

Superficial Formations

Recent :— Alluvium; Peat; Gravel

Pleistocene :— Sand and Gravel; Boulder Clay

Solid Formations

Upper Carboniferous :—

Middle Coal Measures :—(top of division not present).

	Ft.
Thornhill Rock	50+
Measures	35
Joan Coal	
Measures with Tankersley Ironstone	50
Flockton Thick Coal	
Measures with Emley Rock	35
Flockton Thin Coal	
Measures with Parkgate Rock	70
Parkgate Coal	
Measures with Lepton Edge Rock	45

[1] Robertson, G. C. A., 'Farming in Yorkshire,' *Journ. R. Agric. Soc.*, vol. lxxxix (for 1928), 1929.

[2] 'The Threat to the Peak,' Council for Preservation of Rural England (Sheffield and Peak District Committee), *Sheffield*, 1931.

Solid Formations—*continued.*	Ft.
Green Lane Coal	
Measures	45
New Hards Coal	
Measures	40
Wheatley Lime or Clayton Common Coal	
Measures with Falhouse Rock	65
Silkstone or Blocking Coal	
Lower Coal Measures :—	
Measures with Black Band Coal and Sandstones ...	125
Whinmoor Coal	
Measures	30
Cumberworth Thin Coal	
Measures with Penistone Flags and thin coals... ...	130
Grenoside Sandstone Coal	
Grenoside Sandstone	50
Black Bed Coal (in north only)	
Measures	75
Better Bed Coal (in north only)	
Measures with Greenmoor Rock (Elland Flags in north)	210
Upper or Eighty Yards Band Coal	
Measures	80
Lower or Hard Bed Band Coal	
Measures	65
Halifax Hard Bed Coal	
Measures	30
Middle Band Coal	
Measures	30
Soft Bed Coal (Bassy Mine in Lancashire and Cheshire)	
Measures with Woodhead Rock or Soft Bed Flags ...	75
Pot Clay Coal (Six Inch Mine in Lancashire and Cheshire)	
Millstone Grits :—(base not seen).	
Rough Rock and Rough Rock Flags	40 to 140
Shales (with Upper Haslingden Flags in Lancashire)	50 to 140
Upper Meltham Coal (Holcombe Brook Coal in Lancashire)	
Middle Grits: Huddersfield White Rock (Holcombe Brook Grit in Lancashire)	60 to 100
Middle Grits: Shales with Beacon Hill Flags	80 to 250
Middle Grits: Pule Hill Grit, Rivelin Grit or Heyden Rock, (Gorpley Grit in Lancashire)	60 to 150
Middle Grits: Shales with Readycon Dean Series	150 to 300
Kinderscout Grits with interbedded shales ...	500 to 700
Grindslow Shales	300 to 350
Shale Grit	up to 450
Shales	—

References

References to geological literature dealing with the area will be found at the appropriate places in the text. It has not been thought necessary to include a separate bibliography. In 1915 Mr. T. Sheppard published a complete bibliography of Yorkshire geology to the end of the previous year as volume xviii of the *Proceedings of the Yorkshire Geological Society*, and has continued it annually in subsequent volumes. These lists have proved invaluable in the preparation of the memoir.

CHAPTER II

MILLSTONE GRITS

Introductory

This formation is composed of many thick alternating beds of shale and sandstone, with an exposed thickness of at least 2,000 ft. The outcrop covers more than three-quarters of the area of the map, including the most elevated parts.

The shales are similar to those of the Coal Measures; the commonest types are grey and blue clay-shales and mudstones (the 'binds' of the coalfield), but highly micaceous silty and sandy shales and black shales are common. All these types are usually barren except for plant fragments and, near the top of the series, freshwater lamellibranchs. These shales, together with the sandstones, are evidently of freshwater or estuarine origin.[1] There occur, in addition, several thin but well-defined 'marine-bands,' composed of shale which is either dark blue and of a soapy texture or sooty black. These bands are usually crowded with flattened impressions of goniatites and other marine fossils, and occasionally contain impure limestone nodules in which the same fossils occur uncrushed.

Coal seams resting on thin seat-earths are not uncommon and usually but not invariably lie just above sandstone beds. They are for the most part thin and worthless, the notable exception being the Upper Meltham, Holcombe Brook or Simmondley Coal.

Most of the sandstones are coarse and sometimes conglomeratic, and are known as grits,[2] or locally as 'rocks.' They should properly be termed 'arkoses,' being composed of quartz and felspar, chiefly microcline, with small quantities of white mica; the last constituent may be absent, and is never abundant. Several heavy minerals occur, garnet being the commonest. There has been no minute petrological examination of the grits in this area, such as was made by Professor Gilligan in the country to the north.[3] The constituent grains are of various sizes, and in the commonest type of grit some of the quartz occurs as pebbles up to half an inch in diameter, scattered through a finer groundmass. Less frequently the pebbles only occur abundantly on certain bedding-planes. The cementing material may be silica, carbonates of iron,

[1] See for instance, H. C. Sorby, *Proc. Geol. and Polytech. Soc. W. Riding Yorks.*, vol. iii, 1859, pp. 669-675; A. H. Green, 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 23; A. Gilligan, *Quart. Journ. Geol. Soc.*, vol. lxxv, for 1919, 1920, p. 276.

[2] The term 'grit,' denoting relatively coarse grain rather than angularity of particles, appears to be applied universally to the coarser Carboniferous sandstones.

[3] 'The Petrography of the Millstone Grit of Yorkshire,' *Quart. Journ. Geol. Soc.*, vol. lxxv, for 1919, 1920, pp. 251-294.

calcium or magnesium, and in certain cases barytes. Finer-grained sandstones, similar to those of the Coal Measures, are common; they usually contain white mica, often in abundance, and are sometimes flaggy. Both grits and sandstones are usually false bedded.

The denudation of the Millstone Grits, composed of alternations of thick beds of resistant sandstone and soft shale cropping out

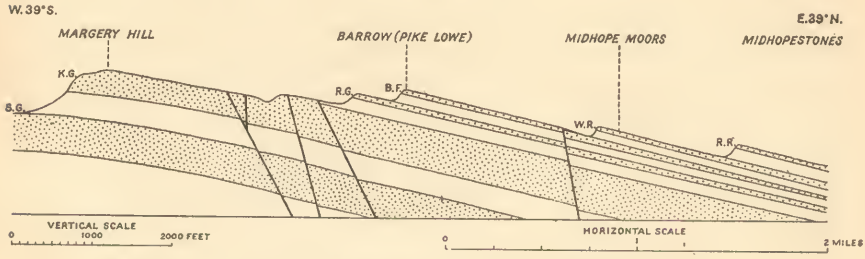

FIG. 2.—*Section from Margery Hill to Midhopestones.*

in an upland area, has resulted in two pronounced types of topography, a modification of the 'ridge and furrow' type and a 'dissected plateau' type. The first is impressed on areas where the dip is appreciable and the faulting is not intense. The hard sandstones form prominent escarpments and dip-slopes, and the shales crop out in the lower slopes of the escarpments and the hollows between. The uncultivated parts of these areas support luxuriant heather, owing to the free drainage of the peat; they form the best grouse moors in the district. This type of topography is seen at its best in the country south of Langsett (Fig. 2). The second type is that seen in the highest parts of the area, particularly

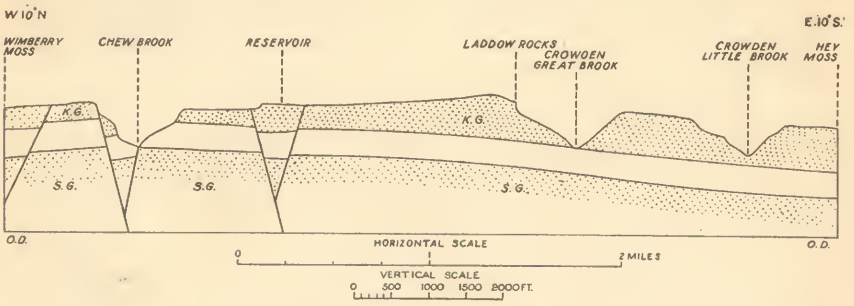

FIG. 3.—*Section across the moors north of Crowden.*

in the Kinderscout Grit country of the western half of the sheet (see Fig. 3). Here the dips are low, and the thick grit beds form high peat-covered plateaux; in these the larger streams have cut deep, steep-sided valleys where the rock scenery is often of surprising wildness and grandeur. These plateaux are drained by large numbers of channels with steep crumbling sides, which start in the peat on the highest ground, and as they descend cut down first

into the clayey layer beneath the peat and then to the grit; eventually they join the larger valleys already mentioned. Sometimes the channels form an intricate maze on broad hilltops, enclosing moundy areas of wasting peat, or running together into wide patches floored with gravel and rock. The streams sweep across flat areas in small meanders, laying down strips of alluvial gravel and sand, which are converted temporarily into tiny terraces by local rejuvenation. Miniature river-captures are common in such areas. The peat of such plateaux is badly drained and the dominant plants are cotton-grasses (see pp. 135, 136).

A great part of the Millstone Grit country forms uninhabited moorlands at altitudes of 1,000 to 2,000 feet with an average rainfall of over 50 in., and is an excellent gathering-ground for water supplies; practically all the moorland area and much of the pasture-land on its flanks is used as such, the chief consumers being the industrial towns on both sides of the Pennines (see pp. 168, 169).

The detailed classification of the Millstone Grits in the table on p. 13 has been made possible by Mr. Bisat's work on the goniatite fauna of the marine bands.[1] These bands are definite horizons which can be traced over wide areas, and are therefore invaluable in correlating the grits and other barren strata which lie between them, a task which has hitherto been impossible. They do not, however, in themselves constitute the zones and subzones to which the names of the goniatites are applied, as the limits of the zones cannot be defined in this region.

The base of the Millstone Grits in this area was at the time of the original survey drawn at the base of the Kinderscout Grit; it has since been repeatedly relegated to lower horizons, so that the present somewhat uncertain base lies far below the rocks described in this memoir. Prior to the publication of the Geology of the Yorkshire Coalfield in 1878 all beds below the Kinderscout Grit were correlated on lithological grounds with the Yoredale Beds of Phillips, the Shale Grit being called the 'Yoredale Grit.' Green, in discussing North Derbyshire and the adjacent parts of Yorkshire[2] showed that the 'Yoredale Grit' could not be separated on lithological grounds from the grits above, and lowered the base of the Millstone Grits to include it. He called it the Pendle or Pendle Hill Grit, or Shale Grit, the latter being the name given to it originally by Farey.[3] The name Yoredale Series was retained for all the beds below the Shale Grit down to the Carboniferous Limestone. The older nomenclature was, however, not changed on the published maps. Wheelton Hind first showed that the shales between the Shale Grit and the Carboniferous Limestone are of newer age than the Yoredale Series of Wensleydale,[4] and the

[1] Bisat, W. S., 'Carboniferous Goniatites of N. England,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 40.

[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 33, and 'Geology of North Derbyshire' (*Mem. Geol. Surv.*), 1887, p. 6.

[3] 'General View of the Agriculture and Minerals of Derbyshire,' vol. i, 1811, p. 228.

[4] *Geol. Mag.*, 1899, pp. 91, 159-169, 205-213.

TABLE OF CLASSIFICATION AND THICKNESS OF THE MILLSTONE GRIT SERIES

Stage	Zones		Subzones	N.W. of Sheet 86	Ft.	Centre of Sheet 86	Ft.	S.E. of Sheet 86	Ft.
Lancastrian	G Gastrioceras		Crenulatum and Cumbriense	Rough Rock and Rough Rock Flags	70-140	Rough Rock	60-90	Rough Rock and Rough Rock Flags	40-80
				Shale Cumbriense marine band Shale	125	Shale Cumbriense marine band Shale	50-120	Shale Cumbriense marine band Shale	130 to 140
			Cancellatum and mut. γ	Cancellatum marine band Shale Upper Meltham Coal		Cancellatum marine band Shale Upper Meltham Coal		Cancellatum marine band Shale Upper Meltham Coal	
	R Reticuloceras		Reticulatum, mut. γ	Huddersfield White Rock	70-80	Huddersfield White Rock	60-120	Huddersfield White Rock	100
				Shale with mut. γ marine band Beacon Hill Flags Shale Late mut. β marine band	120 to 250	Shale with mut. γ marine band	80-125	Shale with mut. γ marine band Sandstone (Beacon Hill Flags) Shale Late mut. β marine band	200 to 250
				Pule Hill Grit	100-150	Heyden Rock	60-80	Rivelin Grit	60-70
		R_2	Reticulatum, mut. β	Shale Mut. β marine band Shale with Readycon Dean Series (Sandstone, etc.) Early mut. β marine band	150 to 200	Shale Mut. β marine band Shale with Readycon Dean Series (Sandstone, etc.)	150 to 300	Shale (mut. β band absent)	150 to 170
			Reticulatum, mut. α	Mut α marine band Kinderscout Grit	700	Mut. α marine band Kinderscout Grit	600	Mut. α marine band Kinderscout Grit	500
		R_1	Reticulatum, type.	Grindslow Shales Shale Grit	350 250+	Grindslow Shales Shale Grit	300 150+	Grindslow Shales Shale Grit	300 450+

Geological Survey later adopted Farey's name, Limestone Shales,[1] for them.[2]

The recent work of Mr. Bisat on the Carboniferous goniatites[3] has made possible the detailed correlation of Millstone Grit developments in different parts of the Pennines, and the Limestone Shales are shown to be the equivalents of the main part of the Sabden Shales of the Pendle region. Dr. Jackson, in a detailed description of these beds in the Edale district,[4] just south of the area here described, shows that they contain in ascending order the middle and upper part of the Eumorphoceras Zone, the Homoceras Zone, and the lowest part of the Reticuloceras Zone. Thus the Shale Grit is of later date than the true Pendle Grit, which belongs to the Eumorphoceras Zone. It is at the same horizon as the thinner Todmorden Grit of the upper Calder, as shown by Messrs. Lloyd and Stephens.[5] The Geological Survey have now extended the base of the Millstone Grits down to the faunal break below the base of the Sabden Shales[6] so that all the beds between the Shale Grit and the Carboniferous Limestone in North Derbyshire are now classed as part of the Millstone Grit Series.

General Stratigraphy

The Shale Grit forms a wide spread on the moors in the southern part of the Sheet, where it is 450 to 550 feet thick. It is also exposed in the valleys of the Etherow and Tame. In the south it consists of grits and sandstones with frequent thin sandy shale beds and less frequent thicker shale beds; in Longdendale the exposed part of the series consists of thicker and more massive grits, but the exposures in the Tame valley show the beds to be more like those in the south.

The grits are often pebbly, but are seldom as coarse or massive as those of the Kinderscout Grit; they usually contain fragments of sandy shale. The sandstones are sometimes ripple-marked, and often show ropy or mammillated bedding-surfaces, which are not, however, confined to the Shale Grit. These surfaces occur where fine-grained sandstones alternate with shales, and are found on the under sides of sandstone beds in contact with shale (see p. 23).

The Grindslow Shales, the equivalents of the Upper Sabden Shales of Calderdale,[7] have been so named by Dr. Jackson, the type-locality being in Edale, 5 miles south of the margin of the map.[8]

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[1] *Op. cit.*, p. 229.

[2] 'Geology of the Southern Part of the Derbyshire and Nottinghamshire Coalfield' (*Mem. Geol. Surv.*), 1908, p. 9.

[3] Bisat, W. S., *op. cit.*

[4] *Journ. Manch. Geol. Assoc.*, vol. i, Part i, 1927, p. 15. See also *The Naturalist*, July 1926, p. 205.

[5] Lloyd, W., and J. V. Stephens, 'The Stratigraphical Succession below the Kinderscout Grit in the Todmorden District,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1927, p. 58.

[6] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 8.

[7] Lloyd and Stephens, *op. cit.*

[8] Jackson, J. W., 'The Succession below the Kinderscout Grit in North Derbyshire,' *Journ. Manch. Geol. Assoc.*, vol. i, part i, 1927, p. 15.

No fossils have yet been found in these shales either by Dr. Jackson in Edale or by the Geological Survey in this area, but a marine bed with *Reticuloceras reticulatum* (Phill.), type (as defined by Bisat), corresponding to that in the Upper Sabden Shales of Crimsworth Dean was once exposed near Greenfield, and was collected from by Messrs. Holroyd and Barnes.[1] It is believed that this marine band is not present south of Greenfield, but as there are no continuous sections in the Grindslow Shales its absence cannot be proved.

The shales, 300 to 350 ft. thick, include mudstones and siltstones with a few inconstant beds of sandstone and grit. They are found in the same three areas as the Shale Grit, forming the concave slopes between the top of that grit and the base of the Kinderscout Grit. The rapid erosion of this great thickness of shale has produced the lofty escarpments capped by the basal Kinderscout Grit which dominate the scenery of Derwentdale, Longdendale and the Greenfield valleys (see Fig. 4, p. 16).

The Kinderscout Grit is from 400 to perhaps 800 ft. thick in this area, being thinnest in the north and south-east. It consists of coarse, massive grit with a number of thin shale partings, the lowest of which, however, sometimes attains a local thickness of over 100 ft. The base is well defined lithologically and, although it appears in places to occupy channels of contemporaneous erosion in the underlying shales, is not so irregular as was formerly supposed.[2] The top is defined by the marine bed containing *Reticuloceras reticulatum*, mut. α and late mut. α Bisat, which either lies close above the grit or is separated from it by only a few feet of shaly beds.

In the north of the area a shale bed with *Lingula* and marine lamellibranchs (the Butterly Marine Band) lies about 50 to 60 ft. below the top of the grit, in a shale parting. Southwards towards Crowden the marine shales appear to wedge out and have not been found farther south. In the country to the north the band can be traced over a wide area, and is taken as the division between the Upper and Lower Kinderscout Grits on the geological map. On this sheet of the map such a division has not been made except where this band can be traced in the north (Fig. 7); the older dual classification in which a lower shale bed was used as the division between Upper and Lower Kinderscout Grit,[3] has been dropped.

Over most of its outcrop the Kinderscout Grit forms wild moorland plateaux, fringed by rugged escarpments and trenched by deep valleys and gorges, making some of the finest rock scenery of the Central Pennines.

The Middle Grits.—All the sandstone beds in the 700 to 800 ft. of strata between the Kinderscout Grit and the Rough Rock are grouped under this heading. The term was introduced when the

[1] 'Rocks and Fossils of the Yoredale Series of the Marsden and Saddleworth Valleys,' *Trans. Manchester Geol. Soc.*, vol. xxiv, 1896, pp. 70-99.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 47.
[3] *Ibid.*, pp. 27, 47, 48.

Kinderscout Grit was regarded as the basal bed of the Millstone Grits;[1] it has lost some of its early significance owing to the downward extension of the Millstone Grit division. The beds are given a distinctive colour on the geological maps.

In this area the four main sandstone beds in the series are, in ascending order, the Readycon Dean Series, the Pule Hill Grit (with its equivalents Heyden Rock, Gorpley Grit and Rivelin Grit), the Beacon Hill Flags and the Huddersfield White Rock (Holcombe Brook Grit in Lancashire). The lowest bed and the Beacon Hill Flags are locally absent, the others are persistent. Other thin local sandstone beds occur, but are not named.

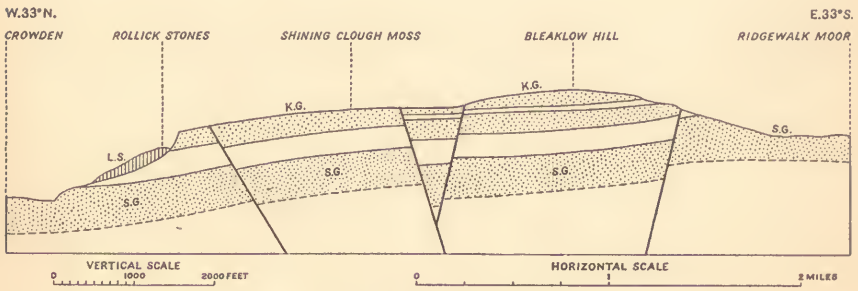

FIG. 4.—*Section across the moors south of Longdendale.*

Associated with these sandstones are several marine beds with the α, β, and γ mutations of *Reticuloceras reticulatum* and in the upper beds species of *Gastrioceras*. All these marine bands are shown in Fig. 8, p. 44, which also shows the distribution and variation of the sandstone beds in the Middle Grits.

The mut. α Band.—A development of shales 40 to 70 ft. thick lies between the Kinderscout Grit and the Readycon Dean Series; where that series is absent shales extend up to the Pule Hill Grit. Except in the central part of the area a thin coal and underclay lie on or close above the Kinderscout Grit. The coal where present is followed closely by the marine bed with *Reticuloceras reticulatum*, mut. α and late mut. α. Occasionally, as at Howels Head (see p. 45), the marine shales rest directly on the grit. The bed appears to be present over the whole area, except possibly around Hollingworth (see p. 47). The distribution of the two mutations found in the bed is discussed in Chapter VII.

Around Marsden an additional marine bed with early mut β is found about 20 to 30 ft. above the mut. α bed, and a bed in the same position but containing late mut. β is seen at Howels Head, on Saddleworth Moor (see p. 45); elsewhere barren shales and mudstones, dark-grey or black in the lower part and becoming gradually sandy towards the top, lie between the mut. α band and the Readycon Dean Series.

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 32.

The Readycon Dean Series is a development of sandstones, grits, tilestones and flags with interbedded shales and occasional ganister and fireclay beds; the sandstones sometimes show the ropy and mammillated surfaces mentioned on p. 23. When traced laterally the series is prone to exhibit sudden extreme variations in thickness and character. It is typically developed in Readycon Dean,[1] and on the neighbouring moors, where it ranges up to 300 ft. in thickness. In the central part of the area it is seldom more than 60 ft. thick, and is sometimes absent (see p. 47). In Woodhead Tunnel it swells locally to 270 ft., but it thins away rapidly to the east. It is thin or absent in the west, south-west and south-east.

The mut. β Band.—Between the Readycon Dean Series and the Pule Hill Grit is a series of shales usually 60 to 70 ft. thick, of interest mainly because of the marine bed near their base characterized by *Reticuloceras reticulatum*, mut. β. In the north-west the bed lies on top of the Readycon Dean Series, but in the centre it is sometimes, as in Heyden Brook, separated from that series by several feet of barren shales. Here two exposures, 30 yards apart, contain respectively mut. β with a few late mut. β and the latter form exclusively, but their exact relation to one another is obscured by slipping. Somewhere in the Saltersbrook Bridge area the bed appears to die out, and it is not seen in the south-east.

The Pule Hill Grit (Heyden Rock, Rivelin Grit).—This is in most places a well-developed bed of grit or sandstone, 60 to over 100 ft. thick. It corresponds to the Third Grit and Main Third Grit of older authors,[2] and to the Gorpley Grit of east Lancashire.[3]

Around Pule Hill the bed is a massive fine-grained grit 100 ft. or more thick. In the central area it consists of sandstone with beds of grit and shale and is usually thinner. There is some doubt about its upper limit here, owing to the absence of the overlying late mut. β band and of the Beacon Hill Flags (see pp. 57, 60). In the Heyden valley it is well developed and exposed and its position in the local sequence clearly marked by the β band below and the γ band some distance above; also the old quarries in it are marked on the map. It is therefore considered expedient to introduce a new name, Heyden Rock, for the bed in this area. In the west it is usually a thick gritty sandstone with a variable amount of flaggy and shaly beds. In the south-east the bed becomes a massive coarse grit 60 to 80 ft. thick, forming strong escarpments. It can be traced southwards beyond our boundary to Strines and Rivelin, and is found to be identical with the Rivelin Grit. This name is now used in the south-east.

[1] Readycon Dean is the valley running in a south-westerly direction, just over a mile north-north-east of Denshaw (see Fig. 6).

[2] See for instance, 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 27.

[3] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 18.

In the central area and around Meltham a parting of estuarine shale, usually containing abundant *Lingula,* divides the grit into a main lower bed and a thin upper bed. The succession appears to be similar to that in the Horwich district of Lancashire,[1] where an estuarine bed separates the main Third Grit from the overlying Helmshore Grit. The thicknesses, however, are much greater in Lancashire. A parting in a similar position is sometimes seen in the west and in the south-east (see pp. 54, 56) but is badly exposed and has yielded no fossils.

The late mut. β Band.—In the north-west and south-east the shales between the Pule Hill Grit and Beacon Hill Flags contain a marine bed at their base, with mutations of *Reticuloceras reticulatum* varying from mut. β to early mut. γ; late mut. β is the commonest form. This marine bed is absent in the centre around Black Hill and Holme; in the west it is present at Mossley. The thickness of the shales varies from about 40 ft. in the north-west to over 100 ft. in the south-east. At Mossley, where the Beacon Hill Flags are absent, the late β and the γ beds are only 40 ft. apart.

The Beacon Hill Flags.—The type-locality for these beds is in the area to the north of our boundary.[2] Around Marsden and Meltham they consist of flaggy sandstone overlain by workable ganister which is up to 12 ft. thick. Their total thickness is up to 30 ft. In the centre of the map the division is absent, or is represented only at certain localities by a thin sandstone bed (see p. 60). It reappears again in the south-east, reaching a maximum thickness on Midhope Moors of about 50 ft. Here it consists of hard pale grey sandstone with a tendency to develop a ganister top. Farther east the bed becomes flaggy and thin, and dies out near the edge of the map. The bed is absent along the western margin, except at Delph where it consists of about 30 ft. of ganister-like sandstone. A flaggy representative is probably present in the Glossop district.

The mut. γ Band.—The shales which overlie the Beacon Hill Flags contain a marine bed which is present over the whole area. Its commonest fossil is *Reticuloceras reticulatum,* mut. γ; *Gastrioceras? sigma* W. B. Wright and *G. lineatum* W. B. Wright are often found associated with it, usually in the upper part of the band.

The marine band lies within 10 or 12 ft. of the Beacon Hill Flags, where those beds are present. It is succeeded by sandy shales which usually pass up gradually into the Huddersfield White Rock. The thickness of the whole shale series varies round an average of 70 to 80 ft.

The Huddersfield White Rock.—The White Rock is in this area the most important member of the 'Middle Grits'; it is

[1] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 12.
[2] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 18.

more uniform in composition and development and occupies a larger surface area than any other, and is in these respects comparable with the Rough Rock.

The upward passage from the shales above the mut. γ marine band to the White Rock is gradual, through alternating layers of shale, sandy shale and flagstone. Accordingly the base of the White Rock is an arbitrary line. The top, however, is perfectly definite; a bed of ganister is succeeded by a few feet of fireclay and a well-marked seam of coal, usually known as the Upper Meltham Coal. The thickness of the rock cannot therefore be definitely stated, but as mapped it is usually about 120 ft. In the Meltham district it has an average thickness of about 80 ft.

At Holmfirth the thickness on the west of the valley is about 80 ft. at Binns Wood, while on the east side it appears to reach 100 ft. In the central plateau, round Holme Moss and Withens Moor, our mapping indicates up to 150 ft., but Green's estimate is 175 ft.[1] In the Dunford Bridge district the figure is 112 ft., but in the south-east it is from 100 down to 70 ft. on the northern side of the Ewden valley.

In composition the rock is normally a medium to coarse-grained sandstone. The lower part is always flaggy, the main mass often thickly bedded. Current-bedding is not often conspicuous, but pillow structures and 'mare-balls' are fairly frequent in the lower beds. In colour it hardly deserves its usual name, given in the Huddersfield area, but is a pale grey: Green (*op. cit.*, p. 53) points out that its appearance is indicated by the names Greystone Edge near the west end of Woodhead Tunnel and Greystones on Sliddens Moss, the latter not marked on the present one-inch map. Shale partings of sufficient size to be mapped occur here and there, as, for instance, to the south and west of West Nab near Meltham.

The top of the White Rock is always a ganister succeeded by a fireclay and the Upper Meltham Coal. West of West Nab the ganister is separated from the main mass by 10 ft. of shale, but south-east towards Upperthong there is no visible sign of such a parting. Across Twizle Head Moss the presence of ganister, indicating the top of the rock, is useful in tracing the position of the important west to east fault.

The economic value of the White Rock is considerable (p. 177); it has been largely used as a building stone in the towns and villages of the Holme valley and its tributaries; there are numerous quarries, for example, on the ridge south of Holmfirth separating the Holme and Ribble (Cartworth) valleys. Important quarries are also found along Banister and Royd Edges south of Meltham where some 30 ft. of fine-grained freestone, white or yellowish in colour, is worked.

[1] 'Geology of Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 54.

The Rough Rock Series.—The beds between the top of the White Rock and the base of the Rough Rock Flags are of great interest. The thickness is about 150 ft. in the north, 100 to 120 ft. from Holmfirth to Dunford Bridge and up to 150 ft. north of the Ewden valley. Usually these beds consist of shale, but south of Meltham a sandstone comes in a few feet above the Cancellatum band; it occupies the surface over a considerable area but does not appear to exceed 30 ft. in thickness. At Wolfstones it is succeeded by a thin coal and about 30 ft. of shale on which rests coarse grit of the Rough Rock. In the adjoining areas to the north and east the sandstone is absent or not traceable but it reappears to the west and south of Langsett. This bed corresponds with the impersistent Moorside Flags of the country to the north[1] and the Lower Haslingden Flags of east Lancashire.[2]

At the base of the series a seam of coal called the Upper Meltham Coal seems to be always present, though only of economic value near the town from which it takes its name; the greatest known thickness of coal is 3 ft. 9 in.; the ganister is 6 in. to 1 ft., and fireclay up to 5 ft. 6 in. Another coal occurs at the top of the impersistent bed of sandstone just mentioned and has been gotten from an open working near Wolfstones.

The chief interest of this series lies, however, not in any economic products, but in the fossils. Two marine bands occur, characterized respectively by *Gastrioceras cancellatum* Bisat and *G. cumbriense* Bisat. Though certain forms doubtfully referred to *Gastrioceras* occur beneath the White Rock in the 'Sigma' band, the Cancellatum band marks the beginning of the dominance of *Gastrioceras* and of the zone to which it gives a name. The upward limit of this zone has not been defined, but it extends a considerable distance into the Coal Measures. The Cancellatum band is usually about 20 ft. above the White Rock; besides the dominant goniatite it yields *Reticuloceras reticulatum* (Phill.), mut. γ Bisat, *Gastrioceras crenulatum* Bisat, *Homoceratoides divaricatum* (Hind), *Dimorphoceras sp.* and *Orthoceras sp.* The characteristic lamellibranchs are *Posidonomya insignis* J. W. Jackson, *Posidoniella multirugata* J. W. Jackson and *Pterinopecten elegans* J. W. Jackson. At Brockholes this band yielded portions of a jaw with teeth of *Edestus newtoni* A. S. Woodward (see Plate V).[3]

The second marine band, that of *G. cumbriense,* is normally about 40 ft. above the lower; *G. crenulatum* is usually more abundant than *G. cumbriense*; forms closely approaching *G. listeri* (Martin) also occur. The lamellibranchs are mostly the same as those of the Cancellatum band, but include *Pterinopecten papyraceus* (J. Sow.). In contrast with the lower band, which may be about 10 ft. thick, the Cumbriense band is not known to

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 21.

[2] 'Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, pp. 22, 23.

[3] Woodward, Sir A. Smith, 'New Species of *Edestus* from the Upper Carboniferous of Yorkshire,' *Quart. Journ. Geol. Soc.*, vol. lxxii, for 1916, 1917, pp. 1-6.

exceed a few inches and is therefore not readily traceable in the field; there is, however, little doubt but that it is invariably present.

Another interesting feature in the palaeontology of these beds is the incoming of *Carbonicola*; this genus has been regarded in the past as typical of the Coal Measures, and its presence in these beds is a further reason for regarding them as more closely linked with the overlying Coal Measures than with the Middle Grits beneath. It appears that there are at least three bands in which *Carbonicola* occurs, respectively below, between and above the two marine bands. Most of the evidence has been obtained from borings, and it is not yet possible to state whether other bands occur or whether the three already known are persistent. The lowest is about 15 ft. above the White Rock and has been proved in the Huddersfield area and in the boring at Oxspring (p. 162); the second was first recorded by Professor Gilligan from Meanwood, near Leeds[1]; the highest has been found in surface exposures near Langsett by Mr. Edwards.

The basal part of the Rough Rock is sometimes distinguishable, as in the country to the north, as flags, indicated on the map by the letters R.F. Elsewhere coarse conglomeratic rock rests directly on shale. South-east of Marsden and west of Meltham the large outlier known as Deer Hill Moss or Scope Moss (Fig. 7) shows some 20 ft. of flags at the base on its northern side, but on the south side they are not distinguishable from the main mass.

East of Holmfirth the basal beds are conglomeratic and to some extent current bedded. Farther south a considerable thickness of flaggy beds is present; at the Magnum Bonum Quarries, shown on the map north of Harden Clough, coarse sandstone rests on coal, dirt and fireclay amounting to 2 ft. which is separated from the valuable flaggy sandstone by 16 to 20 ft. of shale and rag. Towards Langsett the flags die out again and are not distinguishable in the Ewden district.

The Rough Rock itself is well known for its persistence throughout the coalfield as a coarse sandstone. While some bands are correctly described as conglomerate, having pebbles up to an inch in maximum diameter, the greater part would, in the classification now accepted as standard, be called 'gravelly,' that is, having grains above 2 mm. in diameter.[2] In the north, however, the bulk of the rock is of finer grain (coarse sandstone) and has been much quarried. The thickness here is about 80 ft. Around Holmfirth and Hepworth it is only 50 to 60 ft. and the same in the south-east at Midhope and Whitwell Moor. In the intermediate area north of Dunford Bridge, where some 60 ft. of Rough Rock Flags is present beneath, the Rough Rock proper does not exceed 20 ft.

[1] *Trans. Leeds Geol. Assoc.*, pt. xviii, 1920, p. 16.

[2] Boswell, P. G. H., 'British Resources of Sands and Rocks used in Glassmaking,' 2nd Ed., 1918, p. 13.

Details

The Shale Grit.—The moorlands south of Bleaklow Hill, including the Derwent valley, afford the best sections.

Strata below the Shale Grit are only exposed in the right bank of the River Westend alongside the Westend-Smallfield fault. They consist of 15 ft. of grey shale with a few thin fine-grained sandstone bands, and at the bottom of the section several calcareous bullions. The latter proved to be barren. Part of the shale appeared striped in section.

No continuous section of the Shale Grit is available in this district; but the total thickness, judging from the occurrence of its base at the foot of Grinah Grain and taking into account the general dip of the beds, must be between 450 and 520 ft. This agrees with the thickness, 400 to 500 ft., for the same series in north Derbyshire as determined by Dr. J. W. Jackson.[1]

On the south side of the Westend-Smallfield fault the Shale Grit forms a plateau which is deeply entrenched by the gorge-like valleys of the Alport, Westend and Derwent rivers; that of the Westend being nearly 500 ft. in depth.

The general dip throughout this area is to the east-south-east and is slight (average 3°), so that the Shale Grit does not disappear under the Grindslow Shales until the eastern side of the Derwent is reached.

North of the Westend-Smallfield fault (Fig. 15), the top of the Shale Grit appears from beneath the Grindslow Shales at Grains in the Water and thence occupies the bed of the Alport River as far as the fault. In the Westend valley the whole of the gorge is cut in Shale Grit, which eastwards extends across the Ridgewalk and Ronksley moors to Little Moor on the east side of the Derwent. The beds lie almost flat on the moors, but take on a north-easterly dip of 5 to 10 degrees in the Derwent valley.

South of Barrow Stones the Shale Grit is faulted against higher beds, but its top is exposed in the headwaters of the Westend River and in the Derwent south-east of Swains Head, where the dip is northerly.

In character the Shale Grit of this region is a series of arenaceous beds of varying grain with partings of shale and mudstone which are seldom as much as 30 ft. thick and often impersistent. Many of these partings have been mapped on the six-inch scale but owing to their thinness and inconstancy have been omitted from the one-inch map. For instance, three shale bands are mappable for a short distance in Alport Dale, while seven are to be seen on the east side of the Westend valley and three or four in the Derwent valley.

A section in Glethering Clough, a small valley entering Alport Dale from the north-east, was measured and is given below to show the nature of the Shale Grit typical of this area :—

	Ft.
Grit	45 to 50
Shale with thin grit band	5
Grit	12
Section obscured ; probably shale	15
Grit	1
Grey shale	1
Grit	13
Grey shale	2
Grit	9
Grey shale	1
Grit	28
Shale	3
Grit	7
Dark grey silty mudstone	6
Massive grit	2 to 3
Grey shale and mudstone with flaggy beds at bottom...	18

[1] Jackson, J. W., 'The Succession below the Kinder Scout Grit in North Derbyshire,' *Journ. Manchester Geol. Assoc.*, vol. i, part i, 1927, p. 16.

	Ft.
Grit	9
Grey shale	1½
Grit	2
Grey silty shale	3
Grit	11
Shale and tilestone	8
Grit	0¾
Shale	1
Grit	6
Grey shale	3
Grit	36
Black shale	12
Grit, flaggy at top...	30
Shale	1½
Grit	3
Shale	1
Grit	18
Grey gritty mudstone with lenticular grit bed	12
Grit	—

Another section, half a mile west of the southerly bend in the Derwent near Mosley Bank, gives evidence of contemporaneous erosion, a 24 ft. parting of silty shale showing in its lower part turbulent bedding with redeposited ironstone nodules and silty material. Owing to the rapid alternations of thin shale beds with grits and sandstones the streams of this area flow over a continuous series of small waterfalls and cascades, and for the same reason small springs are numerous at many horizons in the sides of the valleys.

In Longdendale the Shale Grit is exposed in the valley bottom, in outcrops disconnected by faulting, between Valehouse and Woodhead reservoirs. The full thickness exposed is probably little more than 150 ft. The beds seen, chiefly in sections along the reservoir banks and in old quarries, consist almost entirely of rather massive grit containing fragments of sandy shale, and sometimes quartz pebbles. There are one or two shaly and flaggy horizons, the one of chief interest, exposed in the banks of Torside Reservoir, containing very good examples of the ropy and mammillated bedding surfaces referred to previously (p. 14). Here, on the north bank about one third of a mile below Crowden Brook, 15 ft. or more of sandy shale, sandstone and flags in thin alternations are visible. The abnormal bedding surfaces occur on the under sides of thin beds of sandstone which are often full of indeterminate vegetable debris. The condition of the underlying shale is not clearly visible.

The commonest type of surface is creased in such a manner as to simulate crêpe, though on a larger scale. Almost as common is a coarsely mammillated surface in which a direction of flow is usually apparent: varying degrees of elongation of the mammillae are seen on different specimens, the extreme cases graduating into those with a crêpe-like surface. Other surfaces show a ropy structure with little or no regularity of pattern; these are sometimes on a very large scale.

The origin of these surfaces has not been fully worked out, but is the subject of further investigation. It is probable that they originated soon after the deposition of the sediments, when the sand was in a state of high viscosity and possessed a definite skin in contact with the underlying shale, and that they are the results of slight movement due to lateral shortening or to creep on gentle slopes, as in the case of deltaic slip. They possess some features in common with the structures mentioned on p. 19 and with the more usual types of subaqueous gliding.[1]

Other surfaces show mineral aggregates up to the size of cherry-stones sticking to sandstone slabs. These may be the work of burrowing animals,

[1] See for instance A. W. Grabau, 'Principles of Stratigraphy,' 1932, pp. 780-785.

but in one case they show a definite orientation. None of these latter types was seen *in situ*, so it is not known on which side of the sandstone they originated.

Of the Shale Grit outcrops in the valley of the Tame there is little to be written, owing to the paucity and poorness of exposures.

There is a thin strip of these beds along the upthrow side of the Tame Fault (Fig. 15), between Stalyhill and Mossley. Probably as much as the top 350 ft. is exposed around Walkerwood Reservoir, where one or two sections show pebbly grit and gritty sandstone with two rather thick beds of papery shale with sandstone bands. An exposure at the north-west corner of the reservoir shows these two shale beds, each about 100 ft. thick, separated by about 100 ft. of gritty sandstone, the beds being bent into a sharp syncline between the Tame Fault and two other large faults.

A larger outcrop occupies the bottom of the valley at Greenfield and is continued northwards past Saddleworth and Harrop Dale to Castle Shaw as a ridge, along the crest of the Pennine anticline. In the southern part of this outcrop, around the lower course of Greenfield Brook, the rocks are much obscured by boulder-clay, but from occasional sections it appears that the uppermost part consists chiefly of grit and gritty sandstone, while below the top 100 ft. or so shale partings and beds of finer-grained sandstone are more common. The grit, as usual, commonly contains abundant fragments of sandy shale.

The best section is that in an old quarry 400 yards west-north-west of Ashway Gap, where is exposed about 60 ft. of grit and gritty sandstone, full of fragments and wisps of sandy shale, and with many badly-preserved plant fragments. There are some partings of sandy shale, and ' ropy ' bedding surfaces (see above) are seen.

North of Greenfield the beds are exposed along the crest of the anticline. Many small exposures show that a considerable thickness (perhaps as much as 450 ft.) is here present of grit and sandstone with beds of blue, grey and black shale. The exposures also indicate the presence of the sharp disturbances and faults trending north and south, described on p. 118. In the cutting at and 500 yards below Diggle Station the highly inclined strata consist of sandstone and grit with beds of blue micaceous shale. The main anticlinal fault (see p. 118) is here splitting northwards into several faults and no estimate of the thickness exposed can be made.

Around Castle Shaw there are several sections in the Shale Grit. In Oaken Lee, Deep and Castleshaw cloughs it consists of a series of massive flaggy grits and flagstones with lenticular bands of sandy shale. North-east of Bleak Hey Nook there are numerous shallow diggings in greyish-brown felspathic flaggy grit. In the ravine south of Bleak Hey Nook (Thorns Clough) there are extensive sections in massive grits with bands of sandy shale, with easterly dips ranging from 50° to 60°.

Farther west there is a smaller outcrop of Shale Grit between Denshaw and Delph. It forms an elevated area in which exposures are poor, and appears to be thinner than in the Saddleworth district. At Ox Hey Top (three-quarters of a mile south-east of Denshaw) it is seen to consist of brown felspathic grit with many lenticular shale partings. It is bounded on the west by a branch of the Tame Fault, and dips under the Grindslow Shales on the east. On the north it is underlain by a series of shales, flags, tilestones and flaggy grits, badly exposed but probably at least 200 ft. thick, which extend down to the stream east of Denshaw. These beds do not resemble the fossiliferous Sabden Shales below the Todmorden Grit in the vale of Calder to the north, and probably they pass laterally into the lower more shaly part of the Shale Grit farther south around Saddleworth.

The Grindslow Shales.—Like the Shale Grit, these beds only crop out in the moorland country in the south, and in the Etherow and Tame valleys.

Thin outliers exist on both Alport and Westend moors, protected by a capping of sandstone. This sandstone is one of two or more thin beds which occur in this area 50 to 100 ft. above the top of the Shale Grit and appear to die out northwards.

East of the Derwent the Grindslow Shales form the concave slope connecting the plateau top of the Shale Grit with the strong escarpment of the Kinderscout Grit which runs below Margery Hill and Rocking Stones, bending westwards across Howden Moors as far as the point where the base of the Kinderscout Grit crosses the Derwent, south-east of Swains Head. They are here 300 to 350 ft. thick, but are poorly exposed.

The features formed by two thin sandstone beds in this series become obscure when traced southwards from Margery Hill, and the beds probably die out altogether near the southern margin of the map. One of them can be traced northwards as far as Rocking Stones, where it probably dies out.

On Howden Moors several copious springs are thrown out by the Grindslow Shales from the Kinderscout Grit, and usually issue from hill-waste some distance below the junction. South of Swains Head the shales are faulted up and form the foundations of the steep hill capped by Barrow Stones. In Barrow Clough (just east of Barrow Stones) the top 200 ft. or so of shales is exposed. They are blue, silty and barren and contain a thin bed of sandstone near the top and another near the bottom. Further thin sandstone and tilestone beds are exposed lower down the stream. Other sections of similar strata are seen in some of the northward-draining streams north-west of Barrow Stones, which form the sources of the Derwent, and in those west of Grinah Stones. West of here the outcrop is traversed by a number of large faults (the Bleaklow Fractures, Fig. 15), so that the shales are thrown now against Shale Grit on one side, now against Kinderscout Grit on the other. In general, however, the series forms a steep hillside running along the south-east side of the Etherow-Derwent watershed into the valley of Shelf Brook, at the lower end of which it ends abruptly against the Blackshaw Fault. South of Shelf Brook the shales form the lower part of Shire Hill, which is capped by Kinderscout Grit.

A bed of flaggy and shaly sandstone is present in the shales north of 'Grains in the Water,' but dies out towards the west, while a grit bed is seen at a slightly higher horizon and can be traced from here round the hillsides to Gathering Hill, just south of Higher Shelf Stones. The bed capping The Ridge farther east is probably the same. A grit bed is exposed in Shelf Brook north of Shire Hill, well over 100 ft. below the Kinderscout Grit, and is possibly the same bed. The Grindslow Shales appear to be about 300 ft. thick in this region.

In Longdendale the shales crop out in the slopes on both sides of the valley between Valehouse Reservoir and Woodhead, and extend up Crowden Great Brook to a point below Laddow Rocks. They are about 300 ft. thick. Exposures are few, the rocks being blanketed with both hill-waste and landslips. Mudstones and shales with sandstone beds are exposed in the stream below the Devil's Elbow. There are occasional exposures of shale and sandstone along the banks of Valehouse and Rhodeswood reservoirs, and mudstones and shales with a bed of grit are seen in Torside Clough just above the railway. This grit bed is evidently thin, and is not seen elsewhere. The flaggy base of the shales is seen at the top of the quarry by the side of the Glossop-Woodhead road, opposite Crowden; grey micaceous shales and mudstones with beds of earthy sandstone, belonging to the upper part of the series, are exposed in places in the streams between Rollick Stones and the Crowden Fault south of Woodhead. South of the Shooting Cabin opposite Woodhead the massive base of the Kinderscout Grit rests on these shales with no sign of a passage but some indication of erosion of the top of the shales. The uppermost beds are exposed between the faults at the confluence of the three Black Cloughs, east of Woodhead; they consist of rather hard grey micaceous shale.

On the north side of the dale the only good section is in Coombes Clough, where most of the series is exposed; it consists of grey micaceous shales and mudstones with beds of soft flaggy sandstone. The lowest beds are faulted out.

The Grindslow Shales crop out in the slopes below the Kinderscout Grit in the Tame valley and its tributaries, between Roe Cross and Denshaw.

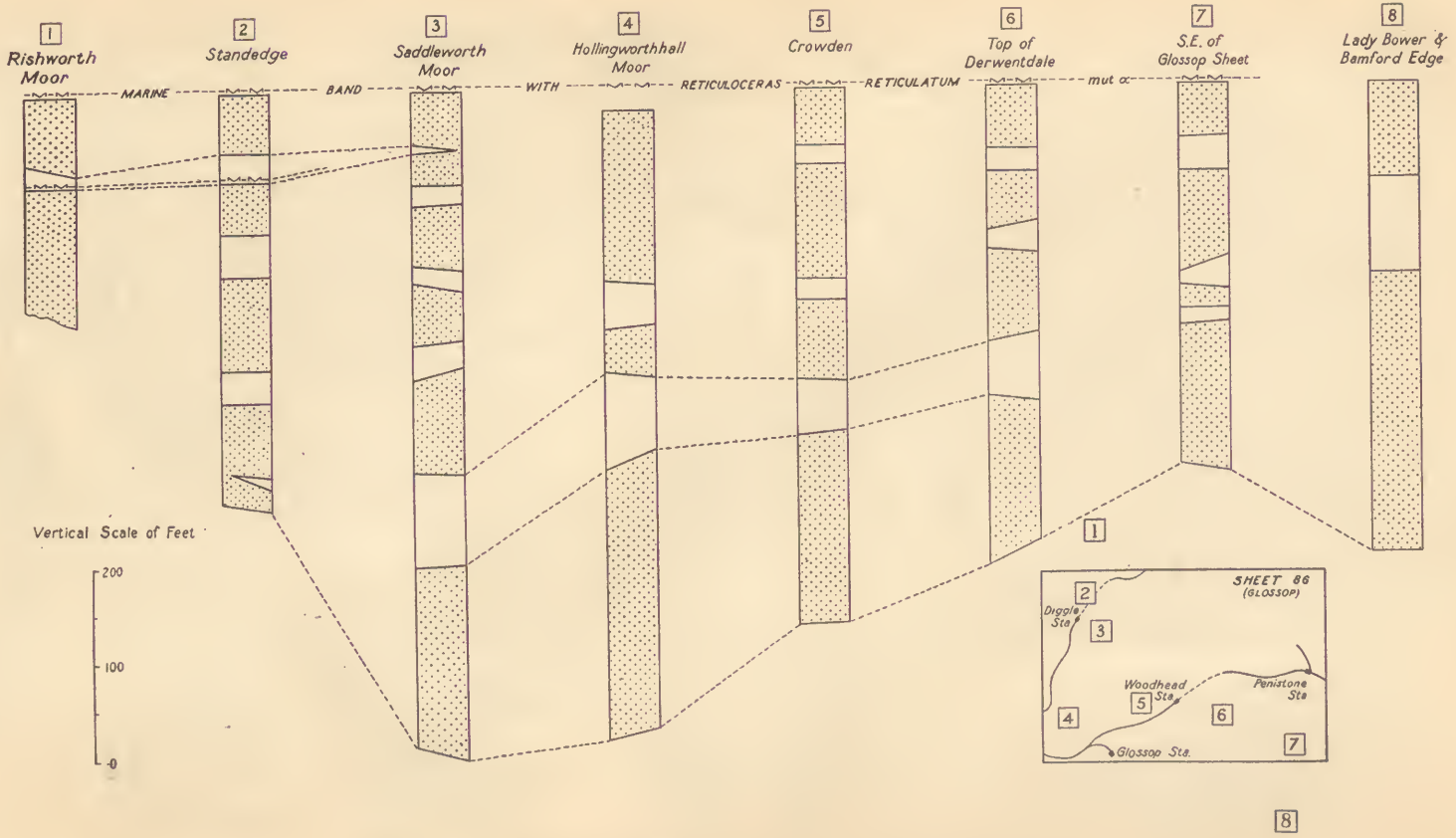

FIG. 5.—*Comparative vertical sections of the Kinderscout Grit.*

From Roe Cross to Greenfield little is seen of them; but they are mainly micaceous shales and mudstones with sandstone and tilestone beds. The best section is in the clough above Micklehurst. In the Greenfield valley there are good sections in the two streams below Wimberry Stones. The series consists chiefly of grey micaceous silty mudstones and shales, with thin beds of silty and earthy sandstone and shaly tilestones. Parts of the succession, including the marine beds discovered here by Barnes and Holroyd,[1] are now obscured and the exact horizon of these beds is uncertain. Some of the goniatites collected have been identified by Dr. J. W. Jackson as *Reticuloceras reticulatum* (Phill.), type form, Bisat.

The Grindslow Shales on the south side of the Greenfield valley are about 350 ft. thick, rather more than the average.

There are many small exposures in the shales on the hillside south of Saddleworth, and about here the beds begin to change from grey mudstones and shales to harder blue shales, under which form they are seen in the Diggle valley and north of Delph. Sandstone beds are rarer here, but beds of tilestone and siltstone occur. A considerable thickness of these blue shales is exposed in the stream below the Rifle Range at Diggle, and in the stream between the Huddersfield road and the line of Diggle Tunnel. The thickness here is about 350 ft., varying locally with the changes in level of the base of the Kinderscout Grit.

Farther north the beds form steep slopes beneath the Kinderscout Grit of Standedge and Castleshaw Moor, swinging across the axis of the Pennine anticline in a wide curve, and dipping south-east at 10 to 30 degrees and north-west at 10 degrees to east and west of the anticline respectively. They are exposed in the cloughs which flow off Castleshaw Moor into the reservoirs, and in the hillside below Standedge, and consist of sandy shales and mudstones with occasional thin tilestone bands, softer and less noticeably blue than the Grindslow Shales of Diggle and Delph. Their thickness here appears to be about 300 ft.

The Kinderscout Grit

To avoid making the detailed account unwieldy, the country over which the Kinderscout Grit crops out has been divided into a number of districts, each of which is described separately, beginning in the north-west of the sheet.

Denshaw to Standedge.—This area embraces the folded and heavily faulted country on the Pennine axis around Denshaw and Castleshaw Moor, and the moorlands of Close Moss and Standedge. It is bounded on the east by the Wessenden Faults and their northward continuations, and extends southwards as far as Round Hill and Bobus.

Massive coarse grits form an area of high ground north of Denshaw. The beds are so faulted and folded that no satisfactory estimate of thickness is possible, but the Kinderscout Grit appears to consist of two main grit beds separated by a shale parting with the Butterly Marine Band (see pp. 15, 145). This bed is exposed in a lane-cutting 500 yds. north-east of Denshaw, and yields *Lingula sp.*

On Castleshaw Moor the sequence is similar, but the strata above the marine bed consist of flaggy grits. In the upper part of Readycon Dean Clough (Fig. 6) the Kinderscout Grit is brought up along a faulted anticline at the north-east corner of Readycon Dean Reservoir; the mut α bed is seen above the grit on both sides of the anticline. At Ragstone, on the Huddersfield road one and a half miles north-east of Denshaw, the lower bed of grit is admirably exposed, forming a weathered crag of massive conglomeratic grit which dips to the north and north-west. Just west of the crag the grit dips steeply into the brook and is overlain by a fireclay and thin coal. South and east of Ragstone the same bed is present and partly encloses a small faulted inlier of Grindslow Shales.

[1] *Trans. Manchester Geol. Soc.*, vol. xxiv, 1896, pp. 70-99.

The base of the Kinderscout Grit can be followed fairly easily round the south edge of Castleshaw Moor to Standedge. The lowest bed is very coarse and massive; it forms crags in Crawshaw Hey and a prominent feature at Broadhead Noddle, on the south-west side of Castleshaw Moor. At Foxstone

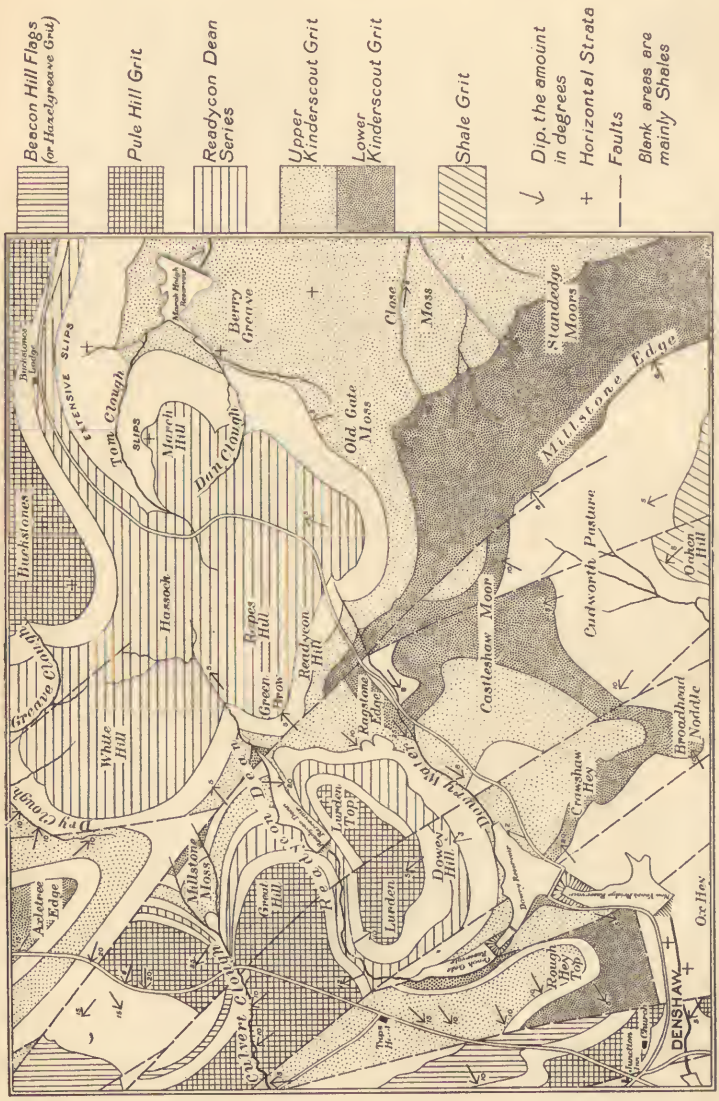

Fig. 6.—*Geological sketch-map of the moorlands to the north-east of Denshaw.*

Brow, close to the north-north-westerly fault across Castleshaw Moor, there is a line of disused quarries showing 15 ft. of hard massive grit slickensided in places; the strong feature here formed by the lowest grit bed ends abruptly against the fault. All along the western edge of Close Moss the Kinderscout Grit forms a well-marked escarpment overlooking the Castleshaw valley. The lowest bed is massive and coarse, sometimes conglomeratic; it forms an almost continuous line of crags and stacks, beneath which the shale slopes are strewn with fallen blocks. In the northern part of Close Moss the Kinderscout Grit consists of four principal beds separated by shales, shaly mudstones and flags.

The three lower beds are massive and conglomeratic and the uppermost consists largely of flaggy grit. The Butterly Marine Bed is present in the top shale parting and lies close above a thin coal. It is exposed at numerous localities on the east side of Close Moss, between Stack End and the railway tunnel; the best section is in Red Brook Clough, 2,500 yards west of Marsden. Here the band has yielded the following fossils:—*Lingula mytiloides* J. Sow., *Orbiculoidea nitida* (Phill.), *Aviculopecten* cf. *carboniferus* (Stevens), *Edmondia josepha* de Kon., and several species of *Sanguinolites, Bellerophon* and *Bucanopsis.*[1]

A good section of the Kinderscout Grit is exposed in the Huddersfield-Oldham road-cutting at Standedge, where its total thickness is 420 ft. The section shows five beds of grit separated by beds of shale and flagstone. The four lower grit beds are massive and conglomeratic, and are separated from the uppermost flaggy and less massive bed by the parting with the Butterly Marine Bed. The lower shale partings have no distinctive features by which they can be recognized in other areas, but each of them, together with the uppermost parting, contains a thin seam of coal and fireclay at its base.

A north-south fault with a downthrow to the west crosses the reservoir just east of the cutting and repeats the higher grits, with the result that the Butterly Marine Bed is exposed at the north-east corner of the reservoir, while the uppermost grit caps the hill to the east (Warcock Hill).

Diggle and Saddleworth to Wessenden Moor.—South of Standedge the outcrop widens out, the grits forming the moors between Saddleworth and Wessenden. On these moors the Kinderscout Grit is over 400 ft. thick, and contains four or more shale partings. The base is irregular; the lowest grit bed of Standedge thins towards the south and passes into shale north of Diggle Rifle Range. The grit above now becomes the lowest bed, and from a thin, though coarse and massive, bed above the Rifle Range swells southwards into the thick grit above Saddleworth. The moor here is covered with large blocks of pebbly grit and there are many old quarries showing sections in 30 ft. or more of very massive grit. The maximum thickness is here about 150 ft. but the bed thins out again south of Saddleworth, while the shale above it thickens from 20 ft. or so east of Diggle to over 100 ft. east and south of Saddleworth. Three, or possibly four, higher grit beds, of coarse massive nature, form part of the moors to the east. Of the shale partings between them, all 20 to 30 ft. thick, the lower ones contain thin inconstant coal seams; the one exposed below the lower reservoir at Black Moss is 6 in. thick and shaly, resting on a foot of seat-earth. The highest parting should contain the Butterly Marine Band, but it is not exposed anywhere.

Massive coarse grits form the high moors east-north-east of Saddleworth, the chief bed exposed sweeping down in a fine dip-slope from White Moss to the fault-scarp along the south-west side of the Wessenden valley. Five thin shale partings are present on these moors, two of them inconstant; the one shown on the one-inch map east of Black Moss contains 3 in. of shaly coal at its base. The correlation of these partings with those in adjoining areas is uncertain, owing to faulting. Shiny Brook Clough and the two cloughs to the north-west afford good sections in the grits, and show the wild scenery of this region at its best. Copious springs break out along the fault-scarp at the foot of the dip-slope in the Wessenden valley.

Delph, Dob Cross, etc.—This isolated outcrop forms a hilly area from Delph to Greenfield Station, with a tongue of high ground extending northwards on the west side of Harrop Dale. On the west the Kinderscout Grit is thrown against much higher strata by the Tame Fault (see p. 119).

The topmost beds of Kinderscout Grit do not occur in the area, but 400 ft. or more of coarse massive grit with three well-defined shale partings is present. Between New Delph and Saddleworth Station the grit is breached by the River Tame. Here and to the south it forms steep hillsides, the base of each bed of grit standing out in a bold ridge.

[1] *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, p. 257.

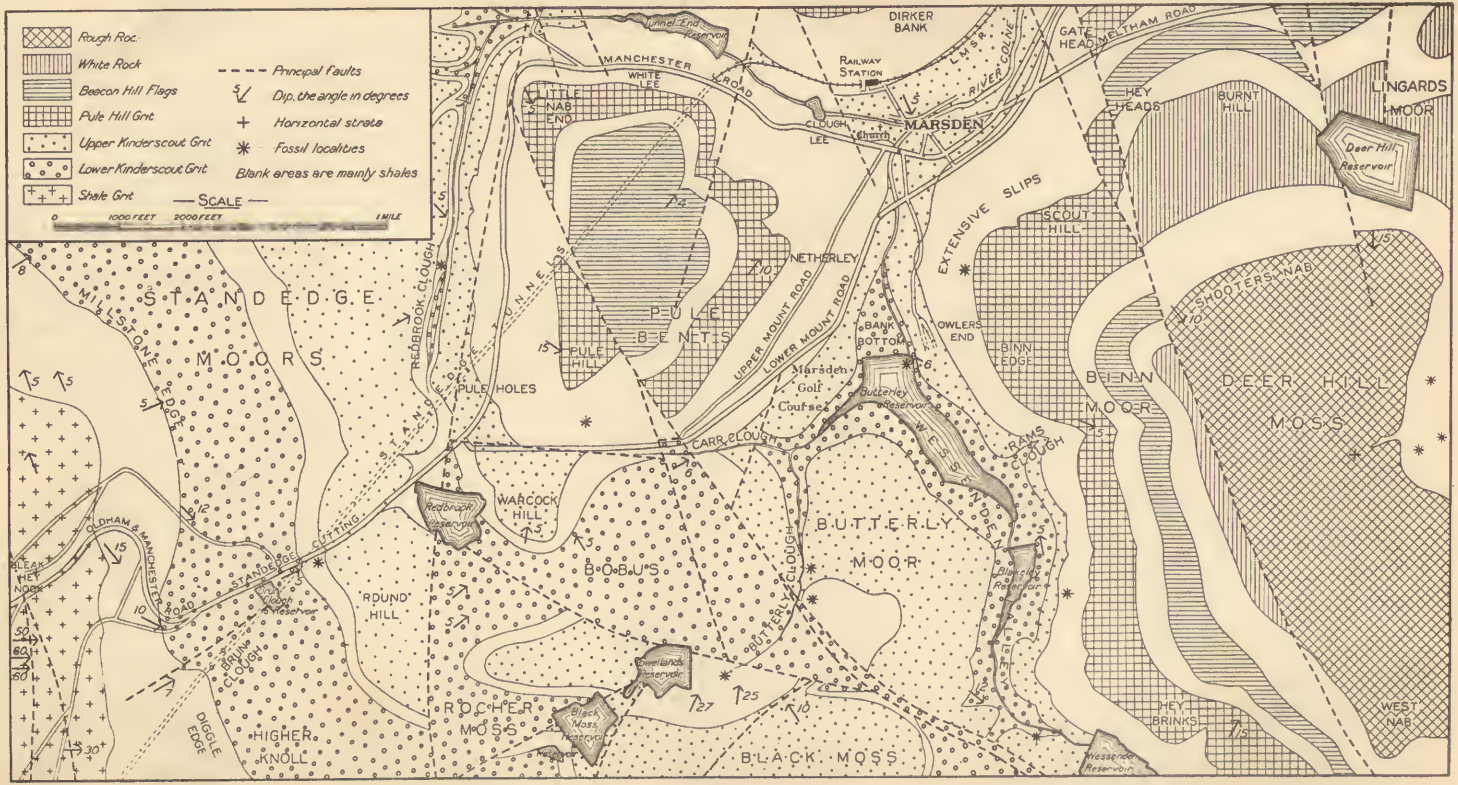

FIG. 7.—*Geological sketch-map of the moors south of Marsden.*

The lowest grit bed caps the small hill just east of Delph (Delph Hill) and forms the tongue of high ground west of Harrop Dale, where it contains an inconstant shale parting. It underlies Saddleworth Station and outcrops along the steep hillside from there to Greenfield, gradually becoming thicker until it forms the prominent hill above Greenfield Station. Here it must be over 300 ft. thick. It has been considerably quarried; at Ladcastle Quarries, above the railway line south of Greenfield Station, the old working-faces show about 140 ft. of massive pebbly grit with inconstant beds of sandy shale up to 20 ft. thick. The shale contains thin sandstone layers. Similar grit with thinner shale partings is exposed nearer Greenfield; in an old quarry west of Greenfield Station the grit is shattered, slickensided, and inclined at an angle of 65 degrees by a nearby fault of no great throw. Other quarries north of Saddleworth Station are worked intermittently for road material and building stone.

The higher grit beds are of similar nature; old openings in them are numerous, but they have never been worked on an extensive scale.

Marsden, Butterly and Wessenden.—This area is bounded by the outcrop of the shales above the Kinderscout Grit except where the Wessenden Faults form the south-western boundary (see Fig. 7).

The uppermost bed of the Kinderscout Grit forms the floor of the Colne valley at Marsden but is limited by faults both to the east and west of the town. Sections in the grit are seen along the railway east of Marsden Station and in the bed of the River Colne. There are also crags of grit along the Manchester-Huddersfield road at Lane Ings, 700 yards east of Marsden Church. The Kinderscout Grit at Marsden is overlain by a prominent band of fireclay with a thin coal. This coal is frequently exposed during excavations; it was recently seen in Town Gate.

South of Marsden the northerly dip makes the Kinderscout Grit rise gradually to higher levels, so that it forms the moor top at Butterly. The embankment wall of Butterly Reservoir (the large reservoir north of Butterly) is largely built on the massive lower part of the Kinderscout Grit; this grit is seen on both sides of the embankment and along the lower slopes of the valley to Wessenden, being exposed in various places. It is overlain by about 20 ft. of shaly mudstone and shale with the Butterly Marine Bed. Above these shales is the upper grit bed, which is not flaggy as in the country to the north-west but massive and thick bedded; its base is marked by a line of springs. About 25 ft. of this bed is exposed on the east of the Butterly Reservoir embankment.

At the bottom of Butterly Clough the lower grit division is well exposed; it consists of three beds of massive coarse grit separated by partings of shale, shaly mudstone and flags. The alternations of these beds produce a series of waterfalls in Butterly Clough, the largest being at the foot of Carr Clough. Higher up Carr Clough the upper beds of Kinderscout Grit, which are here flaggy, are faulted down against the lower conglomeratic beds. The whole of this flaggy division, together with the Butterly Marine Bed below, is exposed in the stream west of the fault, and is succeeded by a fireclay and thin coal, with the mut. α bed above.

The upper parts of Butterly Clough reveal a similar succession. For 500 yards above the foot of Carr Clough the massive and conglomeratic lower division is exposed in the stream. It is succeeded by the shales with the Butterly Marine Band, seen in a good section 600 yards above the foot of Carr Clough. The upper grit division appears in the stream above this point, and is overlain by the mut. α band to the north.

South-east of Butterly Reservoir a gentle syncline brings the Kinderscout Grit below the valley bottom at Wessenden. It reappears beyond the reservoir and forms the floor of the valley up to the reservoir at Wessenden Head. The grit is exposed down to the upper part of the bed below the Butterly Marine Band, a general section being as follows:—

		Ft.	In.
Marine shales (the mut. α bed).	See p. 44	—	—
Sandstone	... ...	3	0
Pebbly grit	... ...	14	0
Coal and black shale	... ...	0	6
Seat-earth	...1 ft. to	3	6
Pebbly grit	... ...	35	0
The Butterly Marine Bed. Dark-grey and black shale with *Lingula*, etc.	... ...	15	0
Grey sandy shale with sandstone beds	... ...	10	0
Pebbly grit	... about	30	0
Black shale with plant impressions ...	... 0 to	1	0
Coal	... 0 to	0	6
Seat-earth	... 0 to	0	6
Pebbly grit	... over	30	0

The upper part of this section, including the Butterly Marine Bed, here rich in *Lingula mytiloides* J. Sowerby, is exposed in the waterfall formed by the overflow from Wessenden Reservoir,[1] and less clearly in the stream-banks above that reservoir. The thin coal in the grit above the marine bed has been found in a number of places around Wessenden, and seems to cover a comparatively wide area. That in the lower grit bed is inconstant; it occurs near the bottom of the stream draining White Moss (Blake Clough), where erosion by the stream of it and the associated soft beds has formed a shapely pot-hole surmounted by a natural bridge of grit. In the neighbouring stream to the north the coal was not seen, but its horizon may be represented by 3 ft. of grey shale, forming a waterfall, or may be obscured lower down the stream. Several pot-holes occur below the waterfall.

In the borehole at Wessenden Head (p. 181) the section of the upper part of the Kinderscout Grit is closely similar to the section above. The Butterly Marine Bed was found in a fresh condition and yielded many fossils.

The outcrops around Mossley, west of the Tame Fault.—The higher beds of the Kinderscout Grit form a long inlier in the Tame valley from near Greenfield to Millbrook, with a smaller inlier around Sidebottom-fold. They consist of the normal massive coarse grits and contain a shale parting 20 to 100 ft. or more thick. The top of the Kinderscout Grit, with the overlying marine shales, is exposed at the east end of the tunnel at the north end of the inlier (Lydgate Tunnel). There are many exposures in massive coarse grit on the west side of the river north of Mossley, in old quarries and railway-cuttings. A quarry south-east of Lydgate shows the uppermost grit bed to contain shaly partings and a thin seam of coal. Grits with the thick shale parting are exposed in the stream valley between Bucktonvale Works and Mossley. The strata are greatly disturbed by faults, but the general section seen at and above the Stalybridge-Greenfield road is :—

	Ft.
Irregularly-bedded grit with sandy shale beds ...	50
Sandy shale and flaggy sandstone	30
Coarse grit with sandy shale partings... ... more than	30

Elsewhere exposures are poor and not numerous, owing to a covering of drift and buildings.

The valleys east of Greenfield and the moors beyond.—This area includes Saddleworth Moor, Dove Stone Moss etc., and is bounded on the east by the outcrop of the beds above the Kinderscout Grit and on the south-east and south by the county boundary of Yorkshire.

[1] Bisat, W. S., *The Naturalist*, 1920, p. 350.

The Kinderscout Grit is here of great thickness. A rough estimate, based on the thicknesses of individual beds, which is all that is possible, makes the maximum thickness about 800 ft., but it is possible that the abnormal thickness of the basal bed may be accompanied by a corresponding thinness of the overlying beds, and that the general thickness here may conform more nearly to that in Longdendale (500 to 600 ft.).

The formation consists of five thick beds of massive, coarse grit, separated by shale partings, of which the three upper are usually 20 to 30 ft. thick, the lowest one being from 20 or 30 to over 100 ft. thick. This parting is usually thickest where the underlying grit is thinnest, and *vice versa*. South of Raven Stones there is an extra shale parting in the upper part of the series, but it cannot be traced elsewhere; other thinner shale beds occur locally.

The basal bed of grit forms a strong feature south of Saddleworth, but it becomes thin near Pots and Pans Stone, and forms a rib in the hillside below the craggy escarpments of the grit above, which forms the hilltop. Here and in the upper part of Greenfield Brook the shale between these two grit beds is about 100 ft. thick, but at the bottom of Holme Clough it is reduced to about 40 ft. Here the grit above rests on it with a very irregular base, suggesting erosion of the underlying shales.

Magnificent cliffs are formed by the upper of these two grit beds at Raven Stones and at Sail Bark Rocks, on the opposite side of the valley (see Frontispiece). North of Greenfield Brook large masses of coarse grit, such as Pots and Pans Stone and Standing Stones, lie about the hilltops; they show the usual effects of subaerial weathering—pot-holes, rain-channels etc.

West of Raven Stones the basal grit is faulted up and is seen to be now of great thickness. From here south to the Chew valley it is about 300 ft. thick, locally somewhat more. From Ashway Rocks its base runs round high up in the hillside into the Chew valley, then westwards below Alphin Pike to Noonsun Hill, the grit forming a splendid line of crags and cliffs, which tower above the steep slopes of the Grindslow Shales, the stream at Greenfield being nearly 1,000 ft. below. At Ashway Rocks the scarp-face has been steepened by ancient landslips, the displaced material covering the slope below down to the reservoir, and leaving bare cliffs above.

The stream above Ashway Gap comes down from the moors in a steep-sided gorge, with precipitous rocks on its south side (Dean Rocks). About 50 to 100 ft. above the base of the grit is an inconstant shale parting, which in the south bank of the gorge is about 50 ft. thick. The shale contains great wedge-shaped lenticles of grit, which may be 10 or 15 ft. thick at one end, wedging out completely at the other end, 30 or 40 ft. away.

The precipice of Great Dove Stone Rocks, a quarter of a mile south-east of Ashway Gap, shows over 100 ft. of massive grit with vertical joints. The grit exposed in the crags south of here is very coarse, some beds being almost conglomerates. There is a good section in the stream north-west of Chew Mount. Below Chew Mount the basal bed of grit is exposed in a deep gorge, above which a line of crags (Dish Stone Rocks) sweeps round the edge of the moor. The Dish Stone, a large mushroom-shaped mass of grit showing undercutting by wind-action, stands near the edge of the crag.

On the south side of the Chew valley faulting causes the base to lie at different levels in the steep hillside. The crags at Stable Stones, by the triangulation point, are the loftiest in the neighbourhood, reaching over 1,600 feet above sea-level. The cliff at Wimberry Stones, about a quarter of a mile farther north-west, has a singularly striking appearance; the grit has weathered along the vertical joints into huge masses, and the dip into the hillside causes the higher beds to overhang the lower. The slope below is strewn with enormous blocks which have descended from the cliff.

West of Wimberry Stones the hillside becames less steep and craggy. The base is shifted a good deal by faults north of Alphin Pike and White Gate, and the lowest grit is here about 200 ft. thick. The grit above appears to be over 200 ft. thick at Alphin Pike.

The scenery of the moorland area east of the Greenfield valley is strikingly different from that which has just been described. A gently undulating plateau, over 1,500 ft. above sea-level, its surface thickly peat-covered, stretches away to north, east and south. Holme Clough and the stream south of Middle Edge Moss flow across the moors in deep ravines. Elsewhere all features are smooth and subdued, the shale partings lying in faint hollows which are often scarcely perceptible. The upper beds of the Kinderscout Grit crop out over this area, and dip generally eastward at very low angles. There are few sections on the moors worth noting. The shale partings have been mapped, but call for little mention. A coal band, consisting of 5 in. of shaly coal and dirt on 6 in. of seat-earth, is to be seen at the base of the third shale parting from the bottom, just north of Holme Clough. Holme Clough affords an excellent section of the Kinderscout Grit from the top of the basal bed upwards. Current-bedded, pebbly grit, sometimes conglomeratic, is exposed all the way up the stream, except for gaps where the three shale partings cross. The stream south of Middle Edge Moss (Birchen Clough) also affords good sections, though not so complete. Stretching from this stream south to the new Chew Reservoir is a tract of badly-drained peat-moss, almost devoid of sections. The shale parting just below the highest ground (spot-level 1,709 ft.) is probably the highest in the Kinderscout Grit, being fifth from the bottom. There are no exposures in it sufficient to show the presence or absence of the Butterly Marine Band. Grit with the shale beds shown on the map is exposed badly in the streams draining into Chew Reservoir. A thin coal smut is present in the bottom of the shale parting south-west of Blackchew Head; this parting is the highest in the grit here, but no trace of fossils was found in it, and the Butterly Marine Band is believed to have already died out in this direction. 'Blindstones,' marked on the map south of Chew Mount, are several large blocks of pebbly grit which lie together above the slight ridge over a shale parting; being surrounded by 6 to 8 ft. of peat they are invisible except at close quarters.

The country around Alphin Pike and Harrop Edge.—This area covers the high ground above Mossley and Millbrook, bounded on the north by the Lancashire county boundary, on the east by the same boundary as far as Swineshaw Reservoirs, and beyond to Roe Cross by the top of the Kinderscout Grit. The grit is faulted down out of sight at the south end of Harrop Edge by the Mottram Fault.

On the west the Kinderscout Grit ends in a fine line of bluffs overlooking the Tame valley, separated by deep gorges occupied by the short, westward-draining streams. These bluffs, Abraham's Chair, the Buckton Castle hill, Harridge Pike, and the top of Wild Bank are formed by the rearing up of the lowest bed of grit in proximity to the Mossley anticline, the crest of which runs parallel with and just below them. Dips as high as 50 and even 70 degrees are seen in the shales just below these bluffs, but the dips flatten rapidly eastwards.

The thickness of the Kinderscout Grit here is estimated at 500 to 600 ft. In the Roe Cross cutting it seems to be thicker, perhaps 700 ft. or more, but it cannot be measured accurately there. Except in the north of the area being considered, the series consists of three beds of coarse, massive grit, the bottom and top beds being very thick, and the middle one thin and partly flaggy. Of the two intervening partings, the lower is about 25 to 100 ft. thick, the upper 30 to 60 ft.

The lowest grit bed is 200 to 300 ft. thick, perhaps more in the south. Large quarries are plentiful, but they are mostly disused except at Harrop Edge. Here the grit is shattered and tilted towards the south-east at 40 to 90 degrees; it contains many partings of dark sandy shale and mudstone.

The shale parting west of Hoarstone Edge is the only one that crops out on the moors here. It appears to represent the higher of the two partings on Slatepit Moor to the south-west, the lower one being apparently missing. It consists of about 30 ft. of barren shale, dark at the bottom and becoming sandy upwards.

All over the area south of Cowbury Dale both partings are present. They are first seen on the west side of Carr Brook, where they make two steps in the hillside. On Slatepit Moor the bottom of the grit between them consists partly of flaggy sandstone, which has been quarried many years ago for roofing-slates; the old excavations along the outcrop are still visible. West of Turf Pits the outcrop of the lower parting is shifted to the west by faults, but at Harridge the two shale beds are again seen close together. Here a stream section shows the lower parting to consist of about 25 ft. of grey micaceous shale and siltstone. The upper parting is probably a little thinner, and the grit between, still with a flaggy base, not more than 60 ft. thick. The grit covering a large area between Turf Pits and Hoarstone Edge is believed to be the uppermost bed of the Kinderscout Grit.

In the Swineshaw valley the stream traverses the Kinderscout Grit in a deep gorge. The complete succession is well displayed on the south side of the valley, the two thick grit beds forming bold features, the shale partings between them being indicated by a pair of parallel depressions. The pronounced south-easterly dip causes the outcrop to be narrow here and to the south.

The section of the Kinderscout Grit on Hollingworthhall Moor is roughly as follows:—

	Ft.
Massive coarse grit	175
Shale	40
Grit, flaggy at the base...	50
Shale	60
Massive coarse grit	275

This section and the one below show that the lower shale parting thickens southward, while the grit above thins.

The middle beds of the Kinderscout Grit are exposed in the road-cutting at Roe Cross. By calculating the thicknesses of the top and bottom beds from the outcrop a complete section may be made:—

	Ft.
Coarse grit (lower 100 ft. only visible) ... about	225
Sandy shale. Much sandstone in lower part ,,	60
Sandstone with shale beds	15
Pebbly grit	20
Shale (only top 60 ft., consisting of dark micaceous shale with sandstone beds, visible)... about	100
Grit, chiefly coarse and pebbly ... ... ,,	300

South of the road-cutting the two shale partings have been traced as far as the Mottram Fault, but the upper bed is ill defined, and either it is becoming more sandy or the thin grit below is passing into shaly beds.

The country around Tintwistle.—This roughly rectangular area stretches north from the fault at Padfield to the county boundary at Boar Flat, the Blackshaw Fault being its eastern boundary. The base of the Kinderscout Grit is not seen, but its total thickness is estimated at 450 to 550 ft. The series is composed of three grit beds separated by two shale partings 20 to 30 ft. thick, which can be correlated with those on Hollingworthhall Moor. The basal grit is sometimes over 300 ft. thick, the two upper beds 50 to 100 ft.

The basal bed occurs between the two converging faults south-east of North Britain, where nearly 200 ft. of grit appears to crop out in the north bank of Ogden Brook. Its higher part is better seen in Longdendale, where it crops out in the banks of Valehouse Reservoir west of the Blackshaw Fault and in the south bank of Bottoms Reservoir for a short distance at the east end. About 30 ft. of coarse grit is seen at the south-east end of Valehouse Reservoir dam, and probably about 150 ft. of grit, with a thin shale parting, crops out in the hillside above. The lower shale bed crops out here and across the valley.

The middle grit bed crops out in the same area, a little higher up the hill-sides. It is abnormally thin on the south side of the valley above Valehouse Reservoir, but thickens south-westwards along the outcrop. On the north side of the valley it is a strong bed of grit 80 ft. or more thick; it crops out on both sides of Townhead and dips down into Bottoms Reservoir, and was shown in the section of the dam-trench, together with part of the shale bed above.[1] It is quarried just above the reservoir (p. 190), the working-face showing about 50 ft. of massive pebbly grit. There are outcrops also in Ogden and Arnfield brooks, in the inliers shown on the map; the rock is about 40 to 50 ft. thick, and flaggy in its lower part. It is also seen in the faulted-up area between North Britain and Boar Flat, where it rests with a flaggy base on the lower shale bed, here below the normal thickness.

The higher of the two shale beds crops out in the inliers just mentioned, where it is 30 to 40 ft. thick, and in Longdendale, where it is slightly thicker. There is a coal seam in it here, indicated by a small spoil-heap of black shale and coal, seen in the fields north of Padfield (see also pp. 40, 41).

The topmost grit forms Boar Flat, Arnfield Moor and Tintwistle Low Moor. It is coarse and current-bedded and appears to be little more than 100 ft. thick. It has been quarried at and north-west of Tintwistle to a depth of 60 ft. South of the Etherow it forms small plateaux on both sides of Padfield; here it contains thin beds of sandstone and shale.

West of the Greenfield-Glossop fault the small inlier at Arnfield Reservoir is badly exposed. That at the bottom of Ogden Brook contains a shale parting 20 to 30 ft. thick, but as it is only 20 to 30 ft. from the top of the grit and the beds above it are flaggy and fine grained, it is evidently a local parting and not the upper of the two partings discussed above. The grit below this shale bed is massive and coarse and is well exposed in the cascade known as 'Devil's Bridge,' 250 yards above the reservoir.

The moors around Crowden.—This district comprises the high moors on the north side of Longdendale, bounded on the north by the Cheshire county boundary and the top of the Kinderscout Grit, and on the west by the Blackshaw Fault. On the south the Kinderscout Grit ends in a line of rocky scarps along the northern side of Longdendale, which, although somewhat dwarfed by the mountainous nature of the opposite side of the valley, are grand and impressive. The base of the grit is over 1,000 ft. above sea-level at Tintwistle Knarr, and falls gradually eastward, reaching the valley bottom just east of Crowden. Farther east the area is bounded by the reservoir bank and the River Etherow.

The Kinderscout Grit is 550 to 600 ft. thick, and consists essentially of four thick and massive grit beds separated by three shale partings, of which the upper two are 15 to 30 ft., and the lower one 40 to over 100 ft. thick. East of Crowden other shale beds come in, of which the thickest is in the lowest grit bed.

The average section at Crowden is:—

	Ft.
7. Massive coarse grit	60 to 90
6. Shale with thin coal at base	20
5. Massive coarse grit	50 to 100
4. Shale	15 to 20
3. Massive coarse grit	80 to 140
2. Shale	40 to 130
1. Massive coarse grit	180 to 200

Three streams, Crowden Great Brook, Crowden Little Brook, and Heyden Brook drain from the moors to the north into Longdendale, and traverse the Kinderscout Grit in deep gorges, noted for the wildness of their scenery which in Crowden Great Brook is particularly fine. In this brook there is a complete

[1] Lapworth, H., 'The Geology of Dam Trenches,' *Trans. Inst. Water Engineers*, vol. xvi, 1911, Figs. 12, 13, p. 42.

section of the Kinderscout Grit, except that the shale partings are badly exposed. The lowest grit (bed 1) forms the cliff west of the Rifle Range called Black Tor; here its massive lower beds have been quarried. It sweeps up the west side of Crowden Great Brook, and is beautifully exposed in a long cascade south of Laddow Rocks, where the footpath to Greenfield crosses the brook (Oakenclough Brook). Its base reaches the valley bottom below Laddow Rocks, where its lower beds crop out in the sides of the narrow gorge. At the right-angled bend in this gorge 60 ft. of wedge-bedded grit is exposed, flaggy in the lower part with inconstant shaly beds. Above this point the brook lies in a narrow V-shaped gorge, with steep rock-strewn sides rising to 200 to 300 ft. Higher and higher beds are seen as one goes up the gorge, the sides meanwhile gradually decreasing in height until the open, peat-covered moors are reached, and the Kinderscout Grit disappears beneath the black shales with the mut. α band (p. 45). The grit beds 3 and 5 are laid bare in the line of cliffs at Laddow Rocks. This is perhaps the finest piece of rock scenery in the district described in this memoir. The shale between the grits, here about 20 ft. thick, forms a slight step in the lower part of the cliff, the grit above it, about 100 ft. thick, forming a sheer precipice. A similar section is displayed in the cliff a quarter of a mile to the south (Rakes Rocks). Bed 5 also forms the two stack-like outcrops higher up the valley, called The Castles. The thin coal at the base of bed 6 is exposed at the cliff-edge at Laddow Rocks, where it is shaly and about 7 in. thick. The highest grit bed (7) makes a minor feature on the moor just behind Laddow Rocks. The east side of the valley is less rugged, but each grit bed forms a prominent rib as it runs along the steep hillside, the bare rock being exposed in places.[1]

The most southerly occurrence known of the Butterly Marine Band (see p. 145) is in the upper part of Crowden Great Brook. It consists of a few feet of blue-black shaly mudstone lying near the base of the topmost grit (bed 7), in the first stream north of Near Broadslate. About 10 ft. of mudstone overlain by grit were seen, but the beds below this were cut off by a small fault. The undermentioned fossils were collected :—

Lingula sp.
Sanguinolites tricostatus (*Portl.*)
Sanguinolites sp.
Pseudamusium sp.
Fish fragments.

No trace of this bed, or of a shale parting on its horizon, is seen in the country to the south.

Crowden Little Brook affords a similar but less complete section of the Kinderscout Grit. In Heyden Brook and its tributary, Withens Brook, the higher beds are well and the lower beds not well exposed, and the base is not seen. In the lower part of the valley there are six shale partings in the Kinderscout Grit, and the special type of scenery resulting from weathering of rapid alternations of hard and soft beds in an area of high relief is beautifully developed. Above Heyden Bridge the stream flows in a gorge which starts at the top of the Kinderscout Grit. The thin coal in the topmost shale bed is present in both the Crowden Little and Heyden valleys. In the latter it is only 3 in. thick.

The lower part of the Kinderscout Grit is exposed in Arnfield Brook, east of the Blackshaw Fault, and in the scarps along the northern side of Longdendale. In Tintwistle Knarr Quarry, above Didsbury Intake, the lowest grit bed is singularly massive, even for this region. The chief divisional planes are widely-spaced vertical joints, bedding-planes being almost absent in an 80-ft. face. The two lower grit beds form the wild cliffs at Millstone Rocks and Lad's Leap, a stream crossing them in a series of cascades. The faults at Millstone Rocks are clearly indicated by the truncated ends of the cliffs. The lowest grit forms a massive feature overlooking Crowden, sweeping down to close above the road west of the church, below which its base is faulted

[1] The upper shale partings cannot be shown everywhere on the one-inch map owing to the narrowness of their outcrops in the valley sides.

almost into the valley bottom; it was penetrated at this point in building the dam-trench of Woodhead Reservoir.[1] It has been quarried above the Rifle Range, providing a massive coarse grit.

The next grit (bed 3) is being quarried at the edge of the hill above (north-east of) Crowden, about 100 ft. of grit being exposed; the grit is flaggy in the lower part and contains large spheroidal concretions. There is a broad 'shatter-belt' near the east end of the quarry, but the vertical displacement is negligible.

East of Crowden the valley side is occupied from top to bottom by the Kinderscout Grit, and the great escarpment of Tintwistle Knarr and Millstone Rocks is replaced here by a number of smaller escarpments, where each bed of grit stands out above the shale below it. With the gentle easterly dip the grit beds sink into the valley bottom as they are followed eastwards, so that at Woodhead Station not more than the top half of the Kinderscout Grit is exposed, and the outcrop on the north of the Etherow has narrowed to a little over a quarter of a mile. The lowest grit contains beds of flaggy sandstone and shale along the hillside north of Woodhead Reservoir. The bottom of the thick shale parting which has been mapped is seen in the quarry above the high-road east of Hey (Enterclough Quarry). Grit has been quarried in several places along the valley between Crowden and Woodhead Station, chiefly close to the roadside. The grit bed (5) caps Pikenaze, where it is more than usually coarse. Bed 3 is exposed at the end of Woodhead Tunnel.

The moor tops in this area call for little description, being almost entirely peat covered and devoid of good exposures. The uppermost grit bed crops out over Bareholme Moss, Hey Moss and Butterley Moss, east of Crowden Great Brook. West of that brook the lower grit beds are exposed on the moors between Arnfield Flats and Laddow Rocks, the strata having a gentle easterly dip. The outcrop of the lowest shale parting (bed 2) runs from the Chew valley over Arnfield Flats and Robinson's Moss, into the escarpment flanking Longdendale at Millstone Rocks. It is repeatedly faulted, but can be traced by the fair escarpment made above it by the base of the next grit. This feature is most pronounced at Windgate Edge and Robinson's Moss. The parting consists of 40 ft. or so of micaceous shale and mudstone with sandstone beds. The next parting (bed 4) crops out on Featherbed Moss and Span, where the outcrop bends north and runs into the cliffs above Crowden Great Brook. It consists of barely 20 ft. of micaceous shale. The top parting (bed 6) is poorly exposed on the moor west of Laddow Rocks.

Surface exposures in numerous water-courses over this moorland area show the grits to be everywhere coarse and pebbly, and usually current bedded.

The Holme Valley Inlier.—An inlier of Kinderscout Grit is exposed in the valley of the Holme above Holmfirth. From a point between that town and Hinchliffe Mill it extends westward up Marsden, Dean and Hey cloughs, south-west past Holme up Rake Dike to the Holme Moss road and southward up Ramsden Clough to near the hamlet of Ramsden. On the east bank of Ramsden Brook and the Holme River the upper margin of the grit is not more than a few hundred yards from the stream.

The strata are mostly grit, sometimes very coarse, with subsidiary shale partings. At the surface three or four such partings are exposed: one is seen in Rake Dike opposite Lane, where it is nearly 30 ft. thick, the top being about 80 ft. below the top of the grit. A shale bed, possibly the same, is exposed in Hey Clough, where part of it is soft and micaceous and contains obscure plant-remains; it forms a noticeable 'slack' on Good Bent End overlooking the two upper branches of Bilberry Reservoir and is also seen in two cloughs below Yateholme Reservoir.

A still higher parting, which has not been recognized elsewhere in the inlier, is exposed in the upper part of Dean Clough, due south of Wessenden Head. It consists of 28 ft. of grey and blue micaceous mudstone with two thin coal streaks in the middle. *Lingula* and lamellibranchs referable to

[1] Lapworth, H., 'The Geology of Dam Trenches,' *Trans. Inst. Water Engineers*, vol. xvi, 1911, Fig. 9, p. 36.

A.—BLACK CLOUGH, WITH BASE OF KINDERSCOUT GRIT.

B.—NATURAL BRIDGE OF KINDERSCOUT GRIT, MARSDEN CLOUGH, HOLMBRIDGE.

To face p. 39]

Sanguinolites are common above the coal, showing the presence of the Butterly Marine Band. As in Wessenden, the bed lies about 50 ft. below the top of the Kinderscout Grit (see pp. 31, 32).

A shale parting at a lower horizon than those just described crops out in the banks of Rake Dike from the waterfall by Holme to the confluence with the stream from Ramsden; it was well seen in excavations for the new reservoir.

One still lower is best seen in Marsden Clough where its presence immediately below a strong bed of grit gives rise to a waterfall, in front of which is the curious natural bridge shown in Plate IIB. It is situated 200 yards below the point where the track crosses, and the banks for a distance of a quarter of a mile downstream are formed of shale overlain by crags of grit; this shale is at least 20 ft. thick, but appears to be barren of fossils. The beds below are mostly pebbly grit, well seen at Bilberry Reservoir.

In the trench for the new reservoir dam between Holme and Holmbridge the rock was seen to a depth of 115 ft. below the level of the river: below this 60 ft. of shale was proved by boring.

At least two thin seams of coal occur in the grits: the higher is visible in Rake Dike at Lane where it is 4 in. thick[1] and in the clough below the western corner of Yateholme Reservoir. A lower seam was exposed at several points in the works for the new reservoir between Holme and Holmebridge; near the dam-trench it was up to 1 ft. thick, resting on a fireclay and accompanied by much crystalline pyrites; it was exposed in the pipe-trench on the main road by the eighth milestone from Huddersfield.

The Derbyshire Moors.—On these moors the lower beds of the Kinderscout Grit form a plateau, mostly over 1,500 ft. above sea-level, and rising at Bleaklow Hill to over 2,000 ft. It is flanked by great escarpments on the north and south, and by the fault-scarp of the Blackshaw Fault on the west. On the east the grit dips under higher beds and the plateau comes to an end, the outcrop continuing into Yorkshire as a great dip-slope sweeping down from the escarpment overlooking the Derwent. The plateau is tilted gently towards the north, so that the highest ground lies just above the southward-facing escarpment (Fig. 4, p. 16).

The thickness of the Kinderscout Grit is difficult to estimate in this region, as there are no continuous sections and the topmost beds are only exposed east of Woodhead. In the west the moors are formed chiefly by the thick lower bed of grit, the bed above being present on Peaknaze Moor and Bleaklow Hill, so that not more than the lower 400 ft. is seen. Farther north-east higher beds come in and it is possible to estimate the complete thickness in the region around Woodhead Station at about 600 ft.; this figure must be considered only a rough approximation. The lowest grit bed is here about 200 ft. thick, and there are four or five shale partings above it, from 10 to 30 ft. thick, separating fairly thick grit beds.

The plateau-surface presents considerable diversity of feature, being crossed by the rocky channels and shallow gorges of the streams, and in the east being thrown into a jumble of scarps and terraces where the Bleaklow Faults traverse the grits and shales in the higher part of the Kinderscout Series. The peat is wasting nearly everywhere, and rock is exposed in many places on the open moors, some of the hilltops, as at Barrow Stones and Bleaklow Hill, being crowned with numbers of large grit blocks, weathered into fantastic shapes and showing pot-holes, rain-channels and the effects of wind-erosion. These blocks are evidently the remains of particularly resistant beds; in some places, especially at Barrow Stones, the ruins of an entire stratum lie thickly over the hilltop, a few blocks still in their original positions, with bedding-planes so weathered as frequently to produce ' Rocking-Stones '; in other places, as at Bleaklow Head, two or three stones alone remain to show where a massive bed has once been.

[1] ' Geology of the Yorkshire Coalfield ' (*Mem. Geol. Surv.*), 1878, p. 49.

The finest physiographical feature of the plateau is the huge escarpment along its northern edge, which extends up the south side of Longdendale from Deepclough to Woodhead in a wall-like line of crags, unbroken except by the short gorge of Torside Clough. The base of the Kinderscout Grit rises from just over 1,000 ft. at the west end of the escarpment to over 1,250 ft. opposite Woodhead, being faulted up in two places. The tops of the crags rise here and there to over 1,500 ft., more than 800 ft. above the valley bottom at Crowden. East of Torside Clough the northerly dip has caused great landslips of the grit over the underlying shales, and the edge of the grit forms almost everywhere a cliff. Between Torside Clough and the Black Cloughs the larger streams approach the escarpment in shallow gorges and plunge over it in a series of waterfalls, the hanging valleys showing as sharp notches in the skyline. The best example is Wildboar Clough, opposite Crowden. Shining Clough, the stream above the shooting cabin opposite Woodhead, is a similar but smaller example.

The basal bed of grit may be examined in natural sections all along the escarpment; it is everywhere coarse and massive. West of the Devil's Elbow a shale parting, which is not seen elsewhere, divides the grit into two beds. The base of the grit is only clearly exposed in Shining Clough (see p. 25).

The great escarpment comes to an end south-west of Woodhead Station where the Crowden Fault throws the Kinderscout Grit down into the valley bottom. The dale narrows abruptly at the station, and the Etherow flows in a gorge over the higher beds of the Kinderscout Grit, being joined on the south by the magnificent ravines of the three Black Cloughs (see Plate IIA). The grits are exposed in the stream and in several old quarries. They were cut through in driving Woodhead Tunnel, about the top 400 ft. being encountered (see Fig. 9).[1] Three shale partings occur in the tunnel and crop out on the hillside east of the station. An additional thin parting with a 6-in. coal seam is shown by the tunnel section to occur about 200 ft. from the top of the Kinderscout Grit, in the middle of the thick grit bed which forms Ironbower Rocks (the line of crags above the road opposite the three Black Cloughs). It is not seen at the surface, but the shale forms a slight feature north-west of the station. The uppermost grit beds extend up the valley as far as Saltersbrook Bridge.

The plateau ends abruptly on the west along the line of the Blackshaw Fault, which throws the massive resistant grits down to lower levels. The lowest grit forms a conspicuous fault-scarp from Blackshaw to Moorside, where it is truncated by the deep valley of Shelf Brook. It reappears south of this brook as the prominent outlier crowning Shire Hill. It is quarried north of Shelf Brook for road material, and more extensively on Shire Hill.

The thickness of the lowest shale parting decreases northwards from 60 ft. or more at Peak Naze and Glossop Low to hardly more than 20 ft. along Bramah Edge and the west side of Torside Clough, where it is exposed at the top of the crags. A small outlier of this shale, capped by the flaggy base of the next grit, forms the hillock called Torside Castle. The shale is about 30 to 60 ft. thick in the country round Bleaklow Hill and Barrow Stones.

The second grit bed forms the conspicuous hill at Peaknaze, north-east of Blackshaw. Its base is flaggy, as in the country to the north-west (see pp. 35, 36). The flags were once quarried on a large scale at Glossop Low, where exposures in the old workings now show about 25 ft. of flags and sandstone, with beds of shale.

The highest parts of the plateau, Bleaklow Hill and Barrow Stones, are formed of this bed, which is very coarse and massive (p. 41). It crops out in the faulted area between Bleaklow Hill and Saltersbrook Bridge, together with the higher grit beds, which are of the usual coarse and massive character, and call for no further mention.

At Peak Naze there is a small outlier of the shale parting above the second grit bed. Old excavations here, the spoil from which contains coal and black

[1] A detailed geological section of the tunnel and air-shafts was prepared by Warington Smyth in 1845 and is in the possession of the Geological Survey.

shale, lead to the inference that a coal seam lies at the base of this shale parting, as at Padfield, a mile westward (see p. 36). It is probably of no great thickness.

The plateau is bounded on the south by an irregular line of steep hillsides and crags, overlooking the Shale Grit moors which stretch away to Kinderscout. The diversity of this southern escarpment, so unlike the wall-like edge along Longdendale, is due partly to the variable nature of the basal bed of the Kinderscout Grit, which is not everywhere thick and massive, but chiefly to the Bleaklow Faults, which have almost cut off the grit areas of Higher Shelf Stones and Barrow Stones from the main outcrop, thus causing the plateau-boundary to pursue a most irregular course; further, these faults prevent the grit base, with its accompanying escarpment, from occupying a constant level for any great distance, and sometimes, as on the south-east side of Bleaklow Hill, throw it in against the Grindslow Shales. In the country east of Bleaklow Hill, where the lowest grit bed is not everywhere strongly developed, the grit above sometimes forms a second escarpment, as at the east end of Bleaklow Hill and at Barrow Stones. The conspicuous crag at Grinah Stones is formed, however, by the lowest bed, which is locally hard and massive.

The basal grit forms fine crags on the north side of Shelf Brook, especially at the Dog Rock and at Shelf Benches. It is here thick and coarse, and in places, as at the Dog Rock, very massive. Above Yellow Slacks and in the valley east of Blakemoor Plantation the lower part of the bed is flaggy and passes down gradually into the Grindslow Shales.

The lowest bed is, as already mentioned, locally thin and less hard east of Bleaklow Hill. Its thickness north of Barrow Stones is less than 100 ft., and the grit is largely flaggy and without pebbles, containing, however, some inconstant coarse pebbly beds. Grinah Stones and Round Hill are formed of coarse pebbly grit, and the bed is probably regaining its normal character in a southerly direction. The grit at Grinah Stones contains roughly spheroidal cavities formed by the erosion of ferruginous concretions.

South-east of Swains Head the Derwent has cut a gorge in the lowest bed of grit, which is thicker than it is below Barrow Stones, but still contains beds of sandstone and shale. The sandstones show ripple marks.

The Glossop District.—A number of isolated exposures of Kinderscout Grit occur in and around Glossop on the west side of the Blackshaw Fault. It is difficult to estimate the thickness of the series in this region, but north of the town the section is roughly as follows :—

	Ft.
Coarse massive grit	70 to 80
Shale with thin coal at base	40 to 50
Coarse massive grit with flags at base	50 to 70
Shale	30 to 70
Coarse massive grit with an inconstant shale parting	300

The total thickness is about 520 feet, but there is a considerable southward thinning, 250 feet being the thickness south of Glossop, just beyond the map. The two shale partings in the above section probably correspond to those on Hollingworthhall Moor (p. 35).

Massive coarse grit in a quarry at the back of Glossop Workhouse represents the beds near the base of the Kinderscout Grit. The rock is shattered on the north side of the quarry owing to the presence of an east-west fault connecting the neighbouring two north-south faults, the Blackshaw Fault and a parallel fault on its west. The grit also crops out on the opposite side of the small valley in the angle between the cross-fault and the Blackshaw Fault. An old quarry in this outcrop shows 30 ft. of coarse grit over 22 ft. of shale and rag. To the south a small outlier of this grit occurs against the western of these two main faults 660 yards east of Glossop Hall. Coarse gravelly grit is exposed in a small quarry in the outlier, and has a dip towards the west-north-west.

Most of the town of Glossop west of the Workhouse Fault is built on Kinderscout Grit. Two faults affect the distribution of the grit. One runs from the Workhouse south-westwards past the Hall to the Greenfield-Glossop fault; the other connects with the first close to the Hall and runs south-eastwards to join the Workhouse Fault near the southern boundary of the Sheet.

In the triangular area between the second of these faults and the Workhouse the Kinderscout Grit lies to the west of the stream, its base running down the course of the stream. The western bank is composed of the flaggy beds at the base of the grit. From 15 to 20 ft. of coarse massive grit, inclined to ' balling,' is exposed in a quarry just north of the cross-roads in Old Glossop, 500 yards north-east of the Hall.

The cross-fault forming the south-western boundary of this area throws up the base of the grit about 30 ft. Consequently, on the west side of this fault the outcrop commences on the north side of the main Glossop-Sheffield road, but, owing to the westerly dip, reaches stream-level close to the centre of the town, 60 yards east of the Glossop-Hayfield road. Crossing to the south side of the stream it swings back, rising towards the east. The only exposure is that in an old quarry on the north side of the Sheffield road, 300 yards east of the station, where 16 ft. of grit and coarse sandstone are exhibited.

The two highest grit beds crop out in the valley south of Blackshaw. North of the Workhouse-Hall fault, which has a large downthrow in that direction, the top of the Kinderscout Grit comes in to form a gentle dip-slope in the angle between that fault and the Greenfield-Glossop fault. There are no exposures.

The Moors north and east of the Derwent.—From the Yorkshire county boundary at Swains Head to the edge of the map south of Broomhead Moor the Kinderscout Grit crops out in a great dip-slope, or more strictly a series of dip-slopes interrupted by faulting and by small shale ' slacks,' which falls away to the north and east from the escarpment along the northern and eastern rim of Derwent Dale, where the basal beds rest on the Grindslow Shales.

The general direction of dip is slightly east of north in the north part of the area, swinging round to north-east in the Ewden valley and changing suddenly to south-east on the south of the Westend-Smallfield Fault. The average amount of dip is 10 to 12 degrees in the north, and 8 to 10 degrees in the south.

As on the Derbyshire Moors, the series consists of three, four or more beds of grit with shale partings between them, the grit being everywhere coarse, pebbly and current bedded.

The thickness on Howden Moors and Harden Moor is estimated at 400 to 500 ft. The series appears to consist just here of four beds of grit, the lowest of which is 140 to 170 ft. thick, and the three above from 40 to 80 ft. thick. The lowest shale parting is from 40 to 80 ft. thick, the upper ones being only 15 to 30 ft.

On the southern border of the map the total thickness appears to have decreased and is probably less than 400 ft. The lowest bed is about 150 ft. thick and at least two shale partings are present above it. The faulting in this area prevents a clear section of the Kinderscout Grit being made.

The lowest bed forms the great escarpment which faces southward and westward across Derwent Dale, beginning near Swains Head, where the river descends over the base of the Kinderscout Grit, and sweeping round in a curve to the edge of the map above Ronksley Wood. The escarpment is everywhere steep and lofty, being comparable with the northern and southern edges of the Kinderscout Grit plateau on the Derbyshire Moors, and contributes largely to the fine scenery of this part of Derwent Dale. The precipitous crags below Rocking Stones and the wall-like edge south of Margery Hill are particularly fine. The grit is exposed nearly everywhere along this escarpment, the best sections being in the courses of the short streams which fall over the steep edge. At Shepherds Meeting Stones

(named on the six-inch map), where the most westerly of these streams has cut a notch in the escarpment, the lowest 70 ft. or so of grit, here very massive, is exposed in a cliff.

Large residual masses of coarse grit lie scattered about the bluff south of Howden Edge. The largest is named the Horse Stone on the six-inch map. The basal grit is about 170 ft. thick at Rocking Stones, where it forms fine crags (called Crow Stones Edge on the six-inch map). Nearly the full thickness is exposed in the precipitous hillside, and two thin inconstant shale beds appear to be present here. Crow Stones, which stand at the top of the edge, are several large weathered stacks of coarse grit forming conspicuous landmarks visible from a wide area to the west.

The heavy faulting west of Rocking Stones has broken up the escarpment into a number of bluffs and embayments, but south of the Slippery Stones—Langsett track (Cut Gate) this lack of continuity disappears and the basal bed of the Kinderscout Grit sweeps southwards to the edge of the map in a fine mural scarp, facing over the Shale Grit plateau and the deep trench-like Derwent valley. It contains one or more shale partings here.

Over the moors which lie north-west of Margery Hill the lowest shale parting crops out close behind the main escarpment, and the grit above forms a small subsidiary escarpment which runs along Howden Edge, much shifted by faults, and forms the isolated ridge nearer the Derwent at Dean Head Stones. North of Howden Moors it is faulted out, but it reappears east of Rocking Stones in the conspicuous crag called Outer Edge (only named on the six-inch map). Along these ridges the grit is usually very massive, but at Dean Head Stones it is thin bedded. Except at Outer Edge it is only exposed in the form of large masses of eroded grit, half buried in the peat. The escarpment at Outer Edge ends in a rugged cliff against the Cut Gate Fault near Bull Stones. South of the fault the second grit bed forms the small outlier at Margery Hill and comes in again some distance down the dip-slope to the east. South of the Westend-Smallfield Fault it is again close to the main escarpment at Featherbed Moss. The highest ground, forming the Derwent-Don watershed, usually lies close behind the second escarpment where it is present.

The higher grit beds form the long slopes which stretch down from the moor tops into the Little Don, Ewden and Agden valleys. They are composed of coarse pebbly grit which is exposed in most of the numerous stream-courses. The shale parting half a mile north-east of Swains Head contains some small Neptunian Dykes, about 6 in. wide, filled with sandy material. The parting which forms a long V in the clough on Harden Moor contains a coal smut, the only one known in the Kinderscout Grit of this area, although others may be present as the shales are badly exposed on these moors. The grit above the shale is probably the highest bed in the Kinderscout series.

Mickleden, the valley draining the westerly Midhope Moors, owes much of its picturesque appearance to the large fault (the Mickleden Fault) which enters it obliquely from the north-west, and cuts off the Kinderscout Grit dip-slope on the west, throwing the top of that formation into the valley bottom, the east side of the valley being formed by the Middle Grits. The edge of the dip-slope of grit, originally a fault-scarp, has been worn back as the valley became deeper and wider, and the shales beneath the grit have been exposed. Under these favourable conditions landslips have broken away from the edge of the grit and lie over the valley side, leaving a steep scarp above them. The topmost beds of the Kinderscout Grit form an inlier in the valley bottom on the east side of the fault, and the stream has cut a small but very beautiful gorge in them. The beds seen are of the usual coarse and current-bedded nature.

Coarse massive grits belonging to the upper part of the series are exposed in the upper parts of Ewden Beck, the stream traversing them in deep gorges.

The two upper beds of grit dip down into Agden Dike at Smallfield, the upper bed forming a strong feature on the south side of the valley, and a

prominent crag on the north side, just west of Agden Lodge. The parting between the two grit beds consists of about 40 ft. of grey sandy mudstone, passing up gradually into the grit above. The upper grit bed is 50 to 60 ft. thick, but the one beneath it is much thicker and forms the wild scenery along the valley west of Smallfield.

The Middle Grits

The Shales between Kinderscout Grit and Readycon Dean Series.—These shales vary in thickness from about 40 ft. to 70 ft. and include the mut. α and early mut. β bands (Fig. 8).

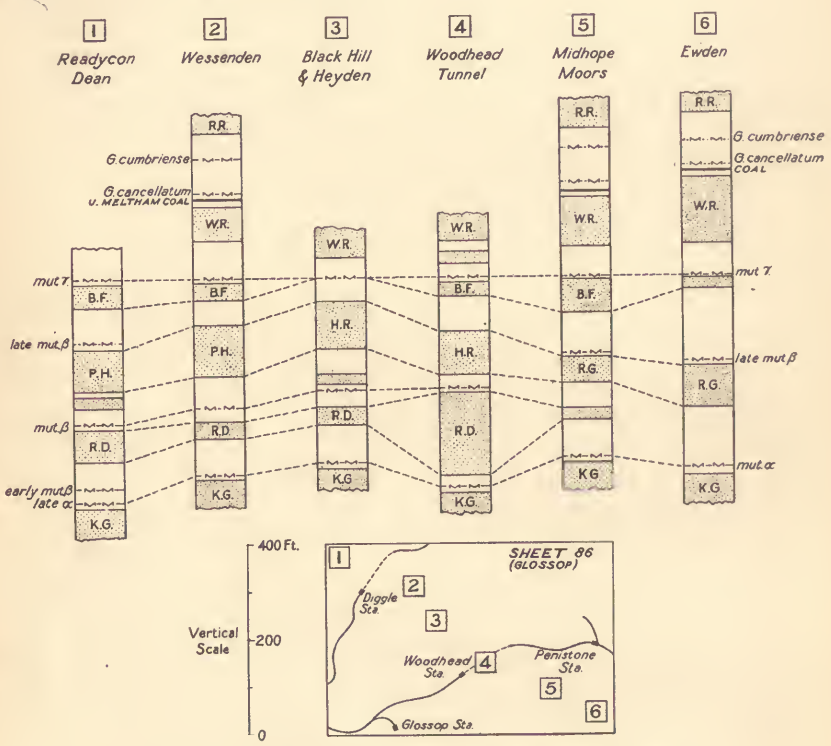

FIG. 8.—*Generalized sections of the Middle Grits.*

1. *The main outcrop from north-west to south-east.*—In the Marsden district a fireclay, usually accompanied by a thin coal, rests on the Kinderscout Grit, and is succeeded by dark shaly mudstones with marine fossils at two horizons about 30 ft. apart. *Reticuloceras reticulatum* is common in both bands, the late α mutation predominating in the lower and the early β in the upper. The upper band is succeeded by soft concretionary sandy mudstones which pass up into the Readycon Dean Series. Both bands are exposed in several good sections around Marsden (see p. 147). Between Marsden and Wessenden Head the early β band has not been found, and is seen to be missing from the section in Shiny Brook (see below).

In the upper part of the Wessenden valley the mut. α band consists of about 12 ft. of black shale crowded with flattened impressions of the index-fossil, including late forms. It lies about 2 to 6 ft. above the Kinderscout Grit, from which it is separated by barren strata, usually sandy, and without a coal seam. It is succeeded by barren blue and grey mudstones, which gradually become sandy and pass up into the Readycon Dean Series some 30 ft. or more above

the marine band. The band is exposed at several places around Wessenden Head (p. 147), the best locality being about 1,000 yards up Shiny Brook. Here the marine shales contain a line of clay nodules at the base and rest on 16 in. of black shale full of fragmentary plants, which in turn rests on the grit. The marine shales contain a rich fauna.

South of Wessenden Head the early mut. β band is again seen in Black Dike, a tributary of Dean Clough; it consists of four feet or more of grey and black shale lying some 25 ft. above the Kinderscout Grit. There are no other clear exposures of either band as far as Howels Head, but small clay nodules with moulds of the α mutation are found in places along the outcrop. An obscure exposure in Holme Clough, at the junction of the two streams from Black Hill, has yielded weathered specimens of the late α and early β mutations; although nearby faults and a thick mantle of peat render accurate mapping impossible, the fossils appear to occupy the horizon of the mut. β band, on top of the Readycon Dean Series.

In the neighbourhood of Howels Head on Saddleworth Moor a difficulty arises in interpreting the fossil evidence. Black shales with *Reticuloceras reticulatum,* mut. α are exposed immediately above the Kinderscout Grit both at Howels Head Flat and in the bed of the stream on the south side of Howels Head. Here they may be seen resting on the grit with a basal layer of calcareous and pyritous nodules partly embedded in its uneven surface. These nodules contain weathered moulds of goniatites.

In the shale bank west and north-west of the Head, the grey shale 20 to 30 ft. above the grit contains small nodules, hardly larger than peach-stones. These, on being split open, disclose external moulds of *Reticuloceras reticulatum,* late mut. β Bisat. This is much the lowest bed, reckoned from the Kinderscout Grit, at which this form has been found. The specimens, which were named by Mr. Bisat before the description of the form was published, have been carefully compared with that now given by him.[1] The mapping has also been checked with a view to finding an explanation of the anomaly, but there appears to be no possibility of a non-sequence in the 30 ft. of strata between the mut. α band and that containing late mut. β, such as would account for the absence of some 120 to 150 ft., including the Readycon Dean Series which should normally intervene between the two marine bands. That series has been mapped without difficulty as a broad belt of sandstone extending from Readycon Dean in the north-west (Fig. 6) to Midhope Moors in the south-east and is definitely just above the Howels Head nodule band. We can only conclude that, although Mr. Bisat's classification of the goniatites has, as a whole, proved invaluable and its other details have been completely established, these subdivisions of mut. β do not form a time sequence, ' late ' mut. β here occurring where ' early ' mut. β would be expected.

The marine band above the Kinderscout Grit is exposed in Crowden Great Brook. Here 10 ft. of black shale with flattened fossils is separated from the grit by 3 ft. of grey micaceous shale. These beds are succeeded by 20 ft. of grey and blue shale with three thin beds of sooty-black shale with goniatites. The α mutation is abundant, together with *Pterinopecten speciosus* J. W. Jackson and a small *Posidoniella.* A further 15 ft. of grey mudstone separates these beds from the nodular sandstone which here forms a well-marked base to the Readycon Dean Series. Rare nodules with moulds of indeterminable goniatites were found in these mudstones, at the level of the Howels Head nodules.

Between Crowden Great Brook and Saltersbrook Bridge the shales are nowhere well exposed except in Heyden Brook. Here black shales with the index-fossil and *Pterinopecten* are seen close above the grit, but higher beds are obscured by landslips.

The spoil-heap of the 2nd air-shaft from the west end of Woodhead Tunnel contains fossiliferous shales from this horizon.

There is a section of the mut. α band in the bank of the Etherow, about 400 yards south of Saltersbrook Bridge. The marine shales with the

[1] ' Summary of Progress ' for 1931, Part ii (*Mem. Geol. Surv.*), 1932, p. 120.

usual fossils are exposed at stream-level, but the beds between them and the underlying grit are not seen. At the lower end of the clough to the south (Far Small Clough) about 20 ft. of sandy shale and sandstone intervenes between the top of the Kinderscout Grit and the marine bed.

From here eastwards across the moors and into the Little Don valley the band is exposed along the outcrop in many places. A typical section measured at the bend in the Little Don three-quarters of a mile south-east of Fiddlers Green is as follows:—

	Ft.	In.
Black marine shale with the usual common fossils ...	9	0
Black earthy mudstone (plant-remains)	2	0
Coal	0	1
Black shale (plant-remains)	0	6
Underclay	5	6
Sandstone passing down into grit	—	—

Barren black shale lies above these beds and passes up into sandy shale, which is succeeded by the Readycon Dean Series 60 to 80 ft. above the Kinderscout Grit. Besides other minor variations from this section there is sometimes a thin ganister bed close above the coal. The thin coal is seen in all the Little Don sections and is persistent, as far as can be seen, over the country to the south-east.

The marine bed crops out in the valley (Mickleden) running north across Midhope Moors, but is badly exposed. The α mutation of the zone-fossil, *Posidoniella minor* (Brown) and a *Pterinopecten* occur here. South-east of Mickleden it is only exposed at one spot, about a mile west-north-west of the bridge at Smallfield. Here the section is:—

	Ft.	In.
Black marine shale ... ... (seen)	5	0
Shaly sandstone	2	0
Dirty coal ... ... 4 to		5
Underclay	1	6
Grey shale	3	0
Sandstone (top of Kinderscout Grit)	—	—

Fossils are abundant and well preserved.

2. *The Holme Inlier.*—Around the Holme inlier the mut. α band is exposed at a number of points, Rake Dike being the locality from which this mutation was first described[1]; the exposure is a poor one, about 300 yards above the road bridge. A better exposure, from which a number of fossils have been collected (p. 147), is in the Holme Woods Dike, immediately above the bridge; the bed is also visible in the next dike eastward, between Holme Woods and Yateholme Reservoir. On the west of the inlier the mut. α band is exposed in Marsden Clough against the Bradshaw Fault; it has also been detected in the little faulted inlier of shale just south-west of Bilberry Reservoir. On the east it is seen in the two little cloughs south-east and south-west of Holmbridge Church, immediately above the top of the Kinderscout Grit.

Above the mut. α marine band are clay shales which pass up gradually through sandy shales into the flags of the Readycon Dean Series, the base of which is therefore indefinite, as in the Wessenden area.

The thickness of the shales between the Kinderscout Grit and the Readycon Dean Series is about 50 to 80 ft. in the Holme inlier.

3. *The South-west of the area.*—The only exposure of the marine band is at the east end of the tunnel at Lydgate, Greenfield. Here shale with mut. α lies close above the top of the Kinderscout Grit.

[1] Bisat, W. S., 'Carboniferous Goniatites of N. England,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 115.

At Hollingworthhall Moor the marine band has not been found, and if present must be at least 30 ft. above the top of the Kinderscout Grit, for south-east of Cock Knarr 30 ft. of barren shales with a thin shaly coal at their base are exposed just above the top of the grit.

Except between Glossop and Padfield the Readycon Dean Series is absent in this region, the strata being shaly right up to the Pule Hill Grit.

The Readycon Dean Series

1. *The main outcrop from north-west to south-east.*—In the Marsden district the mudstones which overlie the early mut. β band pass up into a varying series of flagstones, tilestones, hard ribs of sandstone and occasionally ganister rock, called the Readycon Dean Series. In Readycon Dean Clough they are 300 ft. thick. The series forms a broad flat-topped plateau at and west of March Hill, and is well exposed in the steep cloughs draining east from the plateau.

North of Marsden the series is strongly developed and forms distinctive shelf-like features on the southern slopes of Huck Hill. In Hard Head Clough, north of Stack End, it consists of 80 ft. or more of ganister rock, tilestones, flags and sandy shale, in alternating bands. Rapid local variations are seen in the country south of here.

There is no mappable band of flagstones on the western slopes of Pule Hill, though the steep cloughs between Pule Hill and the village of Marsden exhibit a succession of flagstones and shaly sandstones on this horizon.

On the east side of the Wessenden valley the Readycon Dean Series appears to be absent in the slope below Binn Moor, but reappears just north of Wessenden (Lodge), in the form of several feet of sandy strata with fitful beds of coarse grit.

South-eastwards the series can be followed along the hillside to the reservoir below Wessenden Head, gradually swelling out to a maximum thickness of about 70 ft. It consists of flaggy and gritty sandstone with shale partings; its base is generally 50 to 60 ft. above the Kinderscout Grit.

In the form of a flaggy sandstone, 50 ft. or more thick, it can be followed across the moors from Wessenden Head to Howels Head (see p. 45) and Roundhill Moss, its base making a small but generally sharp feature. South of Dean Clough it consists of two beds separated by about 30 ft. of shale. On these moors it forms small plateaux at Dean Head Hill, Howels Head and elsewhere. Its base is usually 50 to 70 ft. above the Kinderscout Grit; the line of division between sandstone and underlying shale is sometimes well marked, but more often ill defined, the passage from shale to sandstone being gradual, as in the Wessenden area.

East of Crowden Little Brook its thickness decreases, and it forms an indistinct rib in the hillside below Westend Moss (it is not shown here on the one-inch map). It dies out altogether on Heyden Moor, but reappears to the south-east in the form of two thin sandstone beds, the lower one hardly more than 20 ft. above the Kinderscout Grit. Another thin sandstone bed puts in between these two on Withens Moor, and three faint features can be traced from here along the hillside to Salter's Brook.

In the first two shafts of Woodhead Tunnel (see Fig. 9) the Readycon Dean Series is represented by a mass of sandstone and sandy shale up to 270 ft. thick, occupying nearly all the space between the α and β bands. This abnormal thickness is not maintained to the north-east, but falls to about 170 ft. in No. 3 shaft and 140 ft. in No. 4. In No. 1 shaft three sandstone beds stand out among this mass of sediment, and correspond roughly to the beds mapped by the features at the outcrop. They have not been recorded in the other shafts.

At Salter's Brook the features appear to show that the lower two sandstone beds unite to form the bed of flaggy sandstone exposed in the quarry

there.[1] Two bands of sandstone can now be traced across the faults south-east of Salter's Brook, until the upper one dies out south-west of Lady Cross.[2]

The Readycon Dean Series now consists of one sandstone bed, about 30 to 60 ft. thick, which crops out near the bottom of the steep bank on the

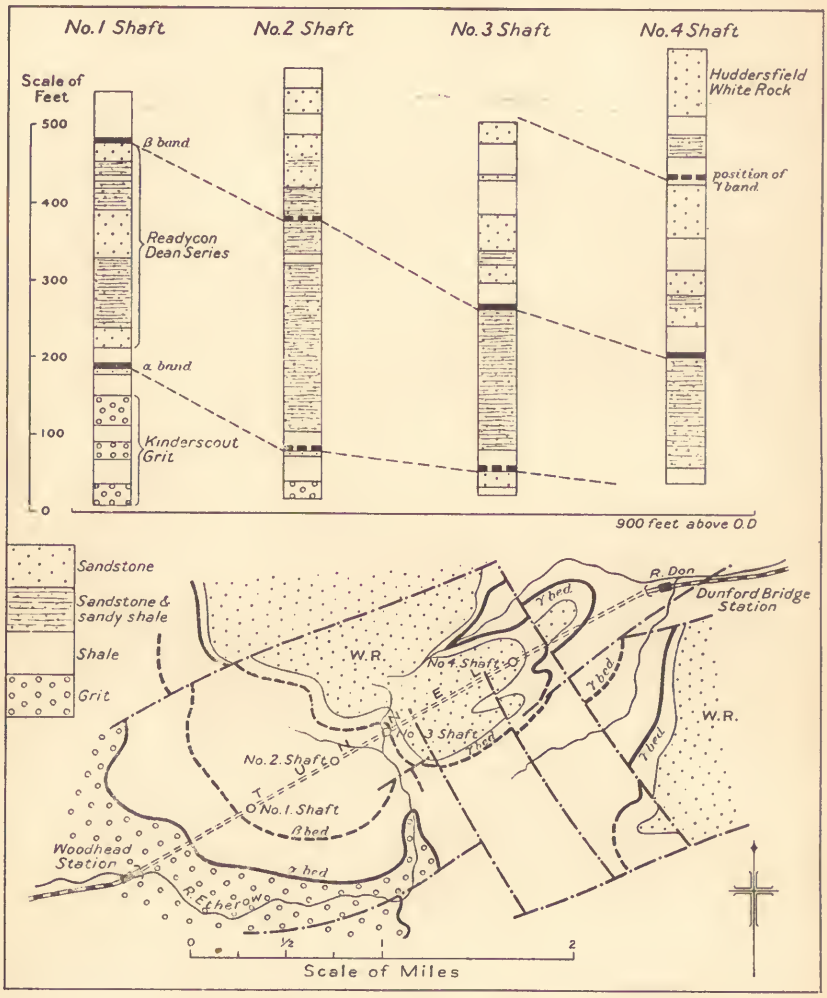

FIG. 9.—*Sections of the shafts in Woodhead Tunnel.*

north side of the Little Don river. It is poorly exposed, and seems to consist chiefly of rather flaggy sandstone with thin shale partings.

Where the edge of the Middle Grits bends south across the Little Don the series is exposed close to the Mickleden Fault, and consists of only about 20 ft. of sandstone with shale beds. It is exposed in the bottom of Mickleden, where it consists of about 22 ft. of similar strata, and forms a

[1] These are shown on the one-inch map as one bed between Withens Brook and Salter's Brook.

[2] Between Withens Moor and Salter's Brook the Readycon Dean Series is hardly anywhere exposed. The poor features made by the harder beds are difficult to follow, and the outcrops above Woodhead Tunnel are laid down by projecting to the surface the beds recorded in No. 1 air-shaft.

narrow outcrop in the steep east side of that valley farther south, running against the fault at the track from Slippery Stones; it reappears in an attenuated form in the wide shale outcrop north of Upper Commons, soon becoming untraceable when followed to the east. It practically dies out here, although sandy beds at the same horizon are found in the Ewden Beck valley. It is not shown on the one-inch map south of the bottom of Mickleden.

2. *The Holme Area.*—Around the Holme inlier of Kinderscout Grit the Readycon Dean Series is a thick mass of flagstones, lying some 50 to 80 ft. above the Kinderscout Grit. As in the country to the west, the clay shales above the mut. α marine band pass up gradually through sandy shales into these flags, the base of which is therefore indefinite. The top is, however, abrupt; the rock is sometimes massive but is succeeded immediately by dark clay shales containing marine fossils with *Reticuloceras reticulatum,* mut. β. In this area the beds have been largely worked along the northern side of the inlier; old quarries at Bradshaw show about 25 ft. of flags, Bingley Quarries, 1 mile farther west, at least 40 ft. North of Holmbridge the flags form a wide dip-slope which has scarcely been touched, but the narrow outcrop north of Burnlee has again been much quarried, 35 ft. being seen at Liphill. On the east of the Holme valley Victoria Quarry is of more recent date than the above, though it has been abandoned in the last few years; it is rather nearer to Hinchliffe Mill than to Holmfirth and shows about 40 ft. of fine-grained even-bedded sandstone with thin partings of mudstone.

On the west of the inlier two small faulted areas of Readycon Dean Series are exposed in the stream north of Dean Clough. The beds consist of alternating tilestones, mudstones, sandy shales and grits. The series is exposed in the upper part of Hey Clough (Issue Clough), where it forms a waterfall.

On the south of the inlier this series forms a shelf in the steep slope from Holme and Twizle Head Mosses and is exposed in the numerous cloughs; the section in Rake Dike is important as *Reticuloceras reticulatum,* mut. β, as well as mut. α was first described from here.[1] It is unfortunate that the generalized section, as given by Mr. Bisat, has been somewhat confused; the flags of this series are recorded as occurring above the mut. β band instead of immediately below it (p. 62); the band is at 1350 ft. O.D., not 1200 as given by Mr. Bisat on p. 63 or 1250 on p. 117 of his monograph; the fossils from this locality are now regarded as late mut. β. In Ramsden Clough the flags are well seen in the bed of the stream below the Rifle Range.

3. *South-west of the area.*—Just north of Glossop the Readycon Dean Series forms the sloping plateau on which stands the Inn east of Bettenhill. It consists of flaggy and shaly sandstone with much interbedded shale, with a maximum thickness on the north of only about 20 ft. It forms, nevertheless, a prominent escarpment overlooking Padfield. On the south side of the plateau it is much thinner and consists chiefly of sandy shale, so that its base can hardly be traced. It appears to lie about 80 ft. above the Kinderscout Grit, the upper part of the shales below it being black but barren.

The interbedded grit, flaggy sandstone and sandy shale, poorly exposed in the cutting south-west of Hadfield Station, is referred to the Readycon Dean Series. Two thin sandstone beds in the cutting just over half a mile from Glossop Station also appear to be at about this horizon.

In other parts of the Glossop and Stalybridge area the series is absent.

The mut. β band (with the succeeding shales)

1. *The main outcrop from north-west to south-east.*—In the Marsden area the marine band is exposed in Hard Head Clough north of Stack End. Here the Readycon Dean Series is overlain by soft black shales with goniatite impressions and small calcareous nodules with goniatite moulds. The Pule

[1] Bisat, W. S., *op. cit.*, p. 117.

Hill Grit lies about 60 ft. above the marine band. On the east side of the Wessenden valley the band is exposed in a gully at Oxhouse farm, 850 yards south of Marsden Church; the goniatites being found in similar states of preservation. On the south-west side of Wessenden Reservoir a few inches of weathered shale with indeterminable goniatites, just above the Readycon Dean Series, is the only other section of the marine bed in the Wessenden valley. The shales between the Readycon Dean Series and the Pule Hill Grit are about 70 to 100 ft. thick here, and are seen in stream sections to be barren to within a few feet of the former, so that the marine bed must be very thin.

The band is not seen between Wessenden and Crowden Little Brook, unless the poor exposure in Holme Clough (p. 45) is on this horizon.

In Crowden Little Brook black shales with the index-fossil and other cephalopods (see p. 149) are exposed just north of the fault between Roundhill Moss and Sliddens Moss. They are closely succeeded by a few feet of sandstone, which can be followed round Westend Moss to the fault north of Binns Moss. The sandstone is absent on the east side of Heyden Brook, but reappears to the east on Withens Moor. Between Sliddens Moss and Heyden Brook the distance from the mut. β band to the Heyden Rock is 60 to 100 ft. or more.

Around Grains Moss the barren shales above the sandstone bed just mentioned are hard and silty, with beds of flaggy sandstone, and appear to pass up gradually into the Heyden Rock on Sliddens Moss. The upper 50 to 60 ft. consisting of dark grey and black shales is exposed in the sides of the Heyden valley.

In this valley the mut. β band is well developed and is clearly exposed in the stream banks for a considerable distance. The best exposures commence about 200 yards below the confluence of the stream from Binns Moss on the west and extend to that from Britland Edge on the east; the shales here have slipped into the valley bottom from a slightly higher position, but the bedding has not been disturbed. A prominent feature is the band of hard calcareous nodules or 'bullions' up to 2 ft. in length; these contain numerous uncrushed goniatites, the hollow chambers of which are usually filled with petroleum; the shale with crushed goniatites and other fossils is at least 6 ft. in thickness; a list of forms collected is given on p. 149. The late β mutation is abundant at this exposure, but mut. β also occurs.

In the northern bank of the stream from Binns Moss and about 150 yds. above the Heyden Brook the band is exposed *in situ*. Bullions are present, though those seen were smaller than at the previous locality; this exposure is less easily accessible, the nodule band being about 15 ft. above the stream level.

The mut. β band is well seen in Withens Brook. It consists of about 6 ft. of rather sandy blue shale, and besides the characteristic goniatite contains also *Lingula*. There are two separate exposures about 100 yards apart and separated by a small fault throwing down to the south-west. The band has not been noted in Salter's Brook and Lady Shaw Dyke and appears to die out altogether in this neighbourhood, for it has not been seen anywhere east of Salter's Brook in the ground under description. The thin sandstone rib above the mut. β band, which occurs in the Heyden Brook area, dies out on the east side of Withens Brook, and between here and Langsett Moors a series of shaly beds, poorly exposed and not measurable with accuracy, separates the Readycon Dean Series from the Heyden Rock. It is possible that there is a *Lingula* band near the top of this shale series as in the Holme district (see p. 51). Specimens of *Lingula* were found on a tip below Greystone-edge Quarries, but the level from which they have come is uncertain.

In Mickleden Beck half a mile above its junction with the Little Don, the following section shows almost conclusively the absence of the marine band:—

	Ft.
Sandstone (Rivelin Grit)	—
Shale and mudstone	50
Sandstone (Readycon Dean Series)	—

The 50 ft. of shale, etc., contains the horizon of the mut. β band; it is further exposed to the north-west, in the right bank of the Little Don, but no marine shales can be seen.

The band has not been found in the country to the south-east between here and the edge of the sheet, although the shales below the Rivelin Grit are exposed in the Ewden Beck and Smallfield valleys.

In Ewden Beck and Agden Dike (the Smallfield valley) about 130 to 140 ft. of shales with a sandy development at about the horizon of the Readycon Dean Series lies between the Kinderscout Grit and Rivelin Grit.

2. *The Holme Area.*—As in the case of mut. α Rake Dike is of importance as the locality from which mut. β was first described (Bisat, *op. cit.*, p. 117); the exposure is, however, not entirely satisfactory as the material is not in place but somewhat dislocated by slipping; the movement has not amounted to more than some 5 ft. The fossils originally recorded from here by Mr. Bisat, before the publication of the generic name *Reticuloceras* and of the mutations, are "*Glyphioceras reticulatum* (abundant and finely preserved), *Posidoniella laevis* (rare), *Dimorphoceras gilbertsoni* (occasional)."[1] Since the completion of the manuscript of this memoir Mr. Bisat has reconsidered the β mutation, and the forms obtained from Rake Dike are now regarded as late mut. β (see p. 45).[2]

Part of a limestone bullion similar to those in the same band at Heyden Clough (above) and containing uncrushed goniatites was found in the stream during the survey; the exposure is on the left bank of the stream at 1,350 ft. above O.D. The band is seen in the Holme Woods Dike at 1,250 ft. above O.D., in the next (Gussett) dike eastwards at 1,200 ft. and in Ramsden Clough at about 1,110 ft. At the last exposure the marine shales could be seen at the time of the re-survey resting immediately on the top of the sandstone which was mammillated, goniatites being found in the hollows between the mammillae. At a subsequent visit this shale had all been washed away by the stream.

On the west side of the Kinderscout Grit inlier the bed is exposed in the dike running north into Dean Clough. Four feet of marine shale is visible, with fossils in a weathered condition, separated from the Readycon Dean Series by 16 ft. of barren shales.

On the northern side of the inlier fragments of shale with marine fossils of this band were noted in Rye Close Lane, half a mile south-west of the Inn by Harden Green Plantation. A more satisfactory exposure is in the northern bank of the lower mill-pond at Black Sike, 3 furlongs south-west of Upperthong village.

Around the Holme inlier the shale between the mut. β marine band and the base of the Heyden Rock is usually about 80 ft. thick; at Hart Hill Springs, 5 furlongs west of Lane, and in Great Dike, 3 furlongs south-west of Holme Woods, a band with dwarf *Lingulae* has been detected in it.

3. *West and South-west of the area.*—Owing to lack of exposures nothing is known of the mut. β band apart from one section south-east of Stalybridge. This is in the stream 300 yards east-south-east of Higher Matley Hall (Westwood Clough); the index-fossil is found, but other forms are rare and consist only of *Posidoniella* and 'Pectens.' The horizon is identical in lithology and fauna with that occurring in east Lancashire about 60 ft. below the Gorpley (=Pule Hill) Grit.

The bed is exposed just beyond the edge of the area shown on the map, one and a half miles south of Glossop.[3] Around Hollingworthhall Moor the shales between Kinderscout Grit and Pule Hill Grit are 150 to 200 ft. thick, the Readycon Dean Series being absent. East of Cock Knarr black shales are badly exposed about 50 ft. below the Pule Hill Grit, but have not yielded fossils.

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[1] *The Naturalist*, 1920, p. 351.

[2] 'Summary of Progress' for 1931, Part ii (*Mem. Geol. Surv.*), 1932, p. 120.

[3] Stephens, J. V., 'Summary of Progress' for 1927, Part i (*Mem. Geol. Surv.*), 1928, p. 44.

The 120 ft. or so of shale between the Pule Hill Grit of Mouselow Castle and the Readycon Dean Series at Bettenhill, north of Glossop, is partly black in the lower half, but not exposed so as to show the marine bed.

The Pule Hill Grit

1. *The main outcrop from north-west to south-east.*—On the moors north of Marsden the Pule Hill Grit forms a broad spread around Huck Hill. Here there are several large disused quarries which show it to be a fine-grained whitish thick-bedded and massive grit.

This grit forms the summit of Pule Hill, the westward-facing escarpment being a prominent landmark in the district (Plate IIIB). A line of quarries along this escarpment shows about 30 ft. of very massive and thick-bedded fine-grained grit. The Wessenden Fault runs about 350 yards north-east of the top of Pule Hill, so that the sloping plateau on that side of the hilltop is formed not of Pule Hill Grit but of Beacon Hill Flags; the Pule Hill Grit crops out at lower levels, forming a prominent shelf all round the north and east sides of the hill. There are large disused quarries at Little Nab End, 1,500 yards north of the top of Pule Hill. Here the grit is massive and thick bedded, and is intersected by parallel joints trending north-west to south-east, and inclined so as to make small angles with the vertical; beds of very hard rock sometimes occur between two such joints. The quality of the stone is marred by the presence of large ferruginous concretions of spherical form up to 3 ft. across, known locally as ' mare-balls.'

East and south-east of here considerable lithological changes take place. The fine-grained grit seen at Pule Hill and Little Nab End passes into a mass of flaggy grits and sandstones with occasional bands of massive grit. The grit in a disused quarry at White Lee, only 600 yards east of Little Nab End exhibits a distinctly flaggy nature. On the hillside south-west of Marsden there are numerous disused quarries; those at Netherley, 800 yards south-west of Marsden Church, exhibit fine-grained massive grit in thick beds with occasional bands of flaggy grit; similar stone is being quarried at Worlow Quarries, 500 yards east of the summit of Pule Hill. In one of these latter quarries the Wessenden Fault is exposed.

The Pule Hill Grit forms a shelf along the south side of the Colne valley north-east of Marsden, and its outcrop, though interrupted by faulting, can be followed southwards into the Wessenden valley. There is an excellent exposure in Bradley Brook, a mile north-west of Meltham Cop. Here a shale parting in the upper part of the grit contains a band with *Lingula* and other fossils, but no goniatites. Although present around Slaithwaite in the country to the north[1] it cannot be traced south and east of Marsden, but the *Lingula* band in the Heyden Rock around Heyden is probably the same.

South-east of Marsden the Pule Hill Grit forms a plateau on Binn Moor. Its base is here not clearly defined; the shales below pass up through a succession of shaly mudstones and thin flags into flaggy grit with occasional thin shale partings. At Scout Holes, 1,000 yards south-east of Marsden Church, a quarry section shows about 30 ft. of false-bedded flaggy grit with beds of flaggy sandstone and bands of sand. The flaggy grit is worked for paving and kerb-stones. Owing to the local north-westerly dip the scarp above Marsden has been steepened by landslips which have slid over the underlying shales down to the outskirts of the village.

Along the east side of the Wessenden valley the Pule Hill Grit forms a strong feature. In Rams Clough, a mile south-east of Marsden, a fine section of the grit is seen, consisting of about 50 ft. of alternating bands of massive flaggy sandstone and flaggy grit, strongly current bedded. At the base is an 8-ft. bed of massive flaggy grit resting on some 15 ft. of shaly mudstone in which are bands of nodular flags and flaggy grit, the thickest of which ranges up to 4 ft. in thickness.

[1] ' Geology of the Country around Huddersfield and Halifax ' (*Mem. Geol. Surv.*), 1930, p. 39.

A.—OUTCROPS OF MIDDLE GRITS, RAMSDEN CLOUGH.

B.—PULE HILL, MARSDEN.

[*To face p.* 52

South-east of Wessenden (Lodge) the Pule Hill Grit is represented by over 100 ft. of current-bedded flaggy sandstone with a few grit beds and many thin shale partings. East of Wessenden a 2-in. coal band lies on top of it. The gradual change from the Pule Hill Grit facies to the Heyden Rock facies is completed at the head of the valley, where the bed has lost its gritty nature and is also thinner. It forms a shelf on the hillside south-east of the Inn[1] at Wessenden Head, but is not exposed. It has been quarried on the west of Bradshaw. Here and to the east it is named the Heyden Rock.

In Harden Clough, north of Harden Green Plantation, the uppermost beds of the Pule Hill Grit are exposed as an inlier; they consist of thick-bedded, flaggy, fine-grained grit, with a distinctly ganister-like top (see section on p. 57).

Between Austonley and Upperthong the Heyden Rock occupies a considerable surface area on the dip-slope, but is probably not more than 20 ft. thick. In the Holme valley north of Holmfirth, where it disappears beneath the surface, the thickness again increases to at least 40 ft., Wood Quarry, above the sixth milestone from Huddersfield, showing 30 ft. of fine flaggy sandstone. South of Holmfirth this rock crops out along the east side of the Holme valley to Ramsden Clough, and also in the floor of the Cartworth valley. In the former there are large quarries at Woodhouse, east of Holmbridge, worked by J. Marsden for sills, ashlar, setts, etc.; the lowest 24 ft. is good sound stone, fine grained and thick bedded; above this is 10 ft. of inferior stone succeeded by 8 to 10 ft. of rag, above which is the shale separating it from the White Rock. There is here no trace of coal, but on the original survey a thin coal was seen at Nabs, on the divide between the Holme and the Cartworth valleys a quarter of a mile south of Holmfirth and at several points in the Cartworth valley.[2] In Ramsden Clough a coal smut on bastard ganister was seen 10 ft. below the top of the sandstone. Between Black Hill and Ramsden Clough the total thickness of the Heyden Rock is about 80 ft., partings being less noticeable than in Heyden Brook.

West of Holme the Heyden Rock is exposed at the upper waterfall in Hey Clough; its top is gritty. Farther west it forms a well-marked shelf on the hillside north of Black Hill. It can be traced across the faults west of Black Hill, and forms the high ground between the two Crowden Brooks at Sliddens Moss. Between the two parallel faults crossing Sliddens Moss from Dun Hill its lower part is a massive sugary-textured gritty sandstone, and forms a small crag. Here the Heyden Rock becomes split by a parting of grey micaceous shale with large specimens of *Lingula* in its lower part, probably the same bed as that seen in Bradley Brook to the north (p. 52). It is best exposed near the top of Crowden Little Brook, where the upper leaf of rock consists of gritty sandstone and the lower of sandstone and shale at the top, and grit at the bottom, with 6 ft. of bastard ganister 6 ft. above the base. On Westend Moss the lower leaf of the Heyden Rock forms a wide spread, flanked on the south by a strong escarpment; it consists of rather gritty sandstone with flag beds. The *Lingula* bed is exposed here, but the upper leaf of rock is thin and is concealed by peat.

In the Heyden valley the rock is probably as much as 100 ft. thick, but includes numerous partings of shale; it is flaggy, somewhat current bedded in the lower part and often ripple-marked in the upper.

South of Britland Edge Hill the lower leaf of Heyden Rock, consisting of sandstone and grit, makes a sharp feature (Dewhill Naze), and is well exposed. The *Lingula* band is seen just north-east of here, but the upper leaf of rock has become a bed of trifling thickness.

Between Withens Moor and Lady Cross there are lenticular grit and sandstone beds on the horizon of the Heyden Rock, but whether the individual outcrops are all on the same level or not is impossible to determine, owing to thick peat on the hillsides and lack of exposures in the streams. The sections of these beds in the Woodhead Tunnel shafts are shown in Fig. 9 (p. 48). There are two sandstones corresponding to the Heyden Rock at

[1] The Isle of Skye Hotel.

[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 55.

Greystone-edge Quarries; the lower consists of about 50 ft. of massive current-bedded sandstone, and has been worked on an extensive scale.

The uppermost beds crop out in the valley south of Dunford Bridge; they consist of flaggy and shaly sandstones, exposed on the upstream sides of the two reservoirs. The higher sandstone between them and the mut. γ band is believed to be Beacon Hill Flags (see p. 61).

South-east of Saltersbrook Bridge there are still two sandstone beds above the horizon of the mut. β band, but here again the upper appears to be Beacon Hill Flags and to lie between the late β and γ bands; the lower, which is roughly on the horizon of the Heyden Rock to the west, can be traced across the moors south of Lady Cross and occupies the position of the Rivelin Grit. In the clough south of Lady Cross it is hardly 20 ft. thick, but it is exposed again near the bottom of the same clough (south-east of Fiddlers Green), where it is a rather gritty sandstone probably at least 50 ft. thick. A marine bed lies close above it and appears to be the late mut. β band, which is frequently seen on top of the Rivelin Grit to the south-east. The sandstone forms a feature along the steep northern side of the Little Don valley (at Hordron Bank), but it is not well exposed.

The Rivelin Grit is the most suitable name for this bed south of the Little Don (see p. 17). At the bottom of Mickleden it crops out on both sides of that valley; it caps the hilltop on the west (Bradshaw Hill), and makes a well-defined feature in the hillside on the east. Here it is divided by a thin shale parting, which dies out farther south. Followed up the east side of Mickleden the Rivelin Grit swells out and forms a fine scarp (Mickleden Edge), along which runs the old pack-horse track to Derwent (Cut Gate). The width of outcrop increases to over a mile on Midhope Moors, where the grit forms a long dip-slope; it narrows again south of the Barrow (Pike Lowe) to just over 200 yards, but here the grit stands out in a bold ridge (Candlerush Edge). In this area the bed is about 60 ft. thick.

Between the Little Don and Candlerush Edge the Rivelin Grit begins to assume the coarse character which is typical of it at Strines, Rivelin, Stanage, etc. (Fig. 10). At the bottom of Mickleden it is a rather flaggy sandstone; halfway up Mickleden Edge the lower beds consist of fine-textured grit, which increases in coarseness southwards, becoming at the top of Mickleden Edge moderately coarse grit with small quartz pebbles. In the stream draining the dip-slope on Midhope Moors the upper beds consist of sandstone and grit, coarse and pebbly in some beds, containing a thin shaly parting, probably the same one that is seen at the bottom of Mickleden. Pebbly grit is exposed along Candlerush Edge, but beds of sandstone are still present.

East of Candlerush Edge the Rivelin Grit crops out on both sides of Ewden Beck, its base reaching stream level near the road-bridge at Ewden. It now consists of 70 to 80 ft. of coarse pebbly grit with sandstone beds in the lower part. The massive and well-jointed character of the rock is reflected in the type of scenery produced by its weathering. The rocky scarps which sweep down from the moors and converge eastwards into the deep and densely-wooded gorge below Ewden form scenery of great beauty.

South of Ewden Beck the Rivelin Grit makes a great dip-slope on Broomhead Moor. The shale parting shown on the one-inch map is probably not above 20 ft. thick; it divides the lower (main) bed of grit from a thin upper bed of flaggy sandstone and sandy shale seen in small exposures along the road south of Broomhead Hall and near Wightwizzle. The parting can be traced beyond Smallfield to the edge of the map, where it appears to die out.

The outcrop on Broomhead Moor terminates southwards in a sharp escarpment (Herculean Edge); there the coarse grit has weathered into crags and stacks; the largest of the latter, called Herculean (more correctly Hurkling) Stones, shows current-bedding on a small scale beautifully etched out by the weather. Well-developed ' pot-holes ' may also be seen in the top of this stack.

The escarpment of Herculean Edge is continued south-eastwards past Smallfield, the grit standing out in a line of crags which overlooks the Agden valley[1] to the south. Here the Rivelin Grit scenery is shown to great advantage. To north and south rocky escarpments crown the valley sides. Between these escarpments the Rivelin Grit is faulted down almost to the valley bottom in a narrow trough, and the stream has cut a wild gorge in the beds below its base, commencing just below the road-bridge (Agden Bridge) and continuing downstream for several hundred yards. The grit north of the stream crops out in crags and stacks, below which the shale slope descends precipitously to the valley bottom.

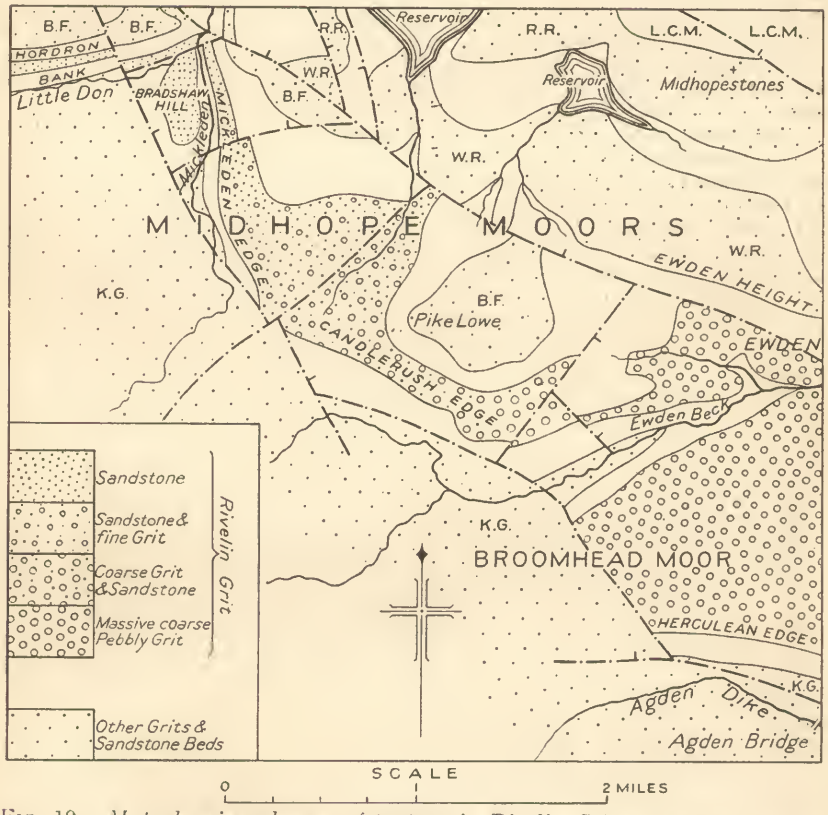

FIG. 10.—*Map showing change of texture in Rivelin Grit on Midhope Moors.*

In its physical characters—grain, composition, jointing, weathering, etc. —the Rivelin Grit of the Agden valley is indistinguishable from the underlying Kinderscout Grit; it gives rise to the same rugged kind of scenery, which is greatly enhanced by the luxuriant woodlands around Agden Bridge.

The thickness of the grit here is estimated to be about 65 ft. Its lower beds are exposed in the numerous crags, and to the extent of about 40 ft. in an old quarry about 650 yards east-south-east of Agden Bridge. Here the massive coarse grits are interbedded with finer-grained flaggy beds in the lowest 15 ft., below an inconstant shaly parting up to 12 ft. thick. The higher beds above the shale parting already mentioned are not exposed south-east of Smallfield.

[1] Not named on one-inch map. Smallfield lies on the north slope of the valley. The stream is Agden Dike.

2. *The Western and South-western districts.*—North-west of Delph the upper part of the Pule Hill Grit is exposed in a small inlier. Sections in the banks of the River Tame below Linfitts show the upper 50 ft. or so to consist of beds of grit and coarse micaceous flagstone.

South of this inlier the grit is next seen on the west side of the Tame Fault at Greenfield. From here the outcrop runs past Lydgate to the edge of the map and then bends south along the western limb of the Mossley anticline, the high westerly dip causing it to stand out as a bold ridge between Lydgate and Mossley. At and east of Lydgate the grit is not well seen, but the shape of the ground and some poor sections show that the main bed of grit is separated from a thin overlying sandstone bed by 10 or 20 ft. of shale. Although lack of exposures leave this point doubtful, it seems probable that this parting contains the estuarine band seen in the centre of the area and in Lancashire (see pp. 18, 53). Along the bold ridge north of Mossley (Quick Edge) several small openings show the bed to consist mainly of massive rather coarse grit.

Just south of Mossley the outcrop descends into the bottom of the valley, and sections along the banks of the Tame show coarse grit with occasional beds of flagstone and shale. Downstream from here the outcrop is faulted westwards, but it crosses the river again opposite Millbrook, and widens out on the crest of the Mossley anticline east of Stalybridge. Here numerous old quarries show fairly coarse grit with partings of dark mudstone. Farther south the brook north-east of Pothouses affords exposures of massive sandstone and coarse flagstone with shale partings. Similar beds are seen in two quarries near Higher Matley Hall.

The presence of the bed is inferred in the faulted area south of Harrop Edge, but there are no surface exposures.

The Pule Hill Grit makes a long dip-slope from the top of Hollingworthhall Moor, and extends north-eastwards in a narrow tongue of high ground, flanked on both sides by a bold scarp, to an abrupt termination at North Britain. A thin shale parting, perhaps 20 ft. thick, occurs about 600 yards north-west of Hollingworth Hall, with a small sandstone outlier above it, 10 to 20 ft. thick. There are no exposures, but the position of the shale suggests that it is the estuarine band mentioned above. There must be 50 or 60 ft. of Pule Hill Grit below the shale, consisting of current-bedded flaggy sandstone with shale partings and a few grit beds. Old quarries near Hollingworth show up to 30 ft. of flaggy sandstone.

The outcrop continues across the Etherow to Hadfield, the lower beds making a strong escarpment facing north. A thickness of 45 ft. of grit is exposed in an old quarry near Hadfield, showing that the lower beds become coarser towards the east.

The sandstone capping the hill on the east side of the Greenfield-Glossop fault just east of Mouselow appears to be Pule Hill Grit. The lowest 25 ft. is seen to be a massive pale-coloured medium- to fine-grained sandstone. A similar rock crops out a little lower down the hill on the west side of the fault, and is believed to be the same bed. It forms a shelf around Mouselow, and is quarried about 200 yards south of that place by John Greenwood. About 40 ft. of stone, probably almost the complete thickness of the bed, is worked for setts, building-stone, etc. The same bed crops out on the south side of the hill, and is much thinner. It is seen near Higher Dinting to contain a similar kind of stone. South of here the outcrop is obscured by boulder-clay, but in the country just beyond the edge of the map the Pule Hill Grit appears to be absent.

The Late mut. β Band

1. *The main outcrop from north-west to south-east.*—In the Marsden area the Pule Hill Grit is succeeded by a series of shales at the base of which is frequently a fireclay and thin coal, the latter being overlain by dark shales containing a marine band characterized by *Reticuloceras reticulatum,* late

mut. β and early mut. γ. This band was formerly exposed in Netherley Quarry and on the eastern slopes of Pule Hill, but the section is now largely overgrown and obscured. A list of fossils from this bed was given by Messrs. Barnes and Holroyd in 1897.[1] Netherley Hill Quarries are 1,000 yards south-south-west of Marsden Church.

An excellent section of the sandy shales which intervene between the Pule Hill Grit and the Beacon Hill Flags is seen in a clough west of New Hey farmstead, 1,000 yards west-south-west of Marsden Church.

The same beds are exposed as an inlier in Harden Clough, north of Harden Green Plantation. The following section was measured 200 yards east of Fox Royd farm :—

	Ft.
Soft shaly mudstones	—
Nodular tilestones and thin flags with shale partings	10
Soft grey shaly mudstones	12
Soft grey micaceous shales with *Reticuloceras reticulatum,* late mut. β and early mut. γ in upper part and plant-remains in lower. Nodules or bullions also occur with casts of goniatites ...	2
Thin rib of hard ganister-like sandstone	1
Soft micaceous shales with very abundant plant impressions	2
Rather massive flaggy and ganister-like sandstone in bed of stream (Pule Hill Grit)	3+

The shale parting between the Pule Hill Grit and Beacon Hill Flags can be traced up the east side of Wessenden to the fault south-west of West Nab. It is about 30 to 40 ft. thick and has a coal smut 2 to 4 in. thick with a fireclay at its base. The shales give rise to a prominent hollow or ' slack,' but they are poorly exposed and the late mut. β band has not been found here. The same shales are present on both sides of the main road at the Isle of Skye Hotel, beneath the capping of Beacon Hill Flags on which the inn stands. All over the country between the ' Isle of Skye ' and Langsett Moors, and in the Holme valley, the late mut. β band has not been seen, although sections in the strata at its horizon are plentiful. It seems certain that in much, at least, of this area the band is absent. In places, particularly around Holme Moss, the top of the Heyden Rock is very close to the mut. γ band, so that the shale parting in which the late mut. β band was usually seen in the north of the area cannot be traced. In Ramsden Clough, however, the Heyden Rock is separated by 50 ft. of shale from a 10-ft. sandstone bed overlain by the mut. γ bed. The sandstone may be the Beacon Hill Flags, but the late β band is definitely absent from the shales below.

On Langsett Moors the late mut. β band reappears, and the sections here and to the south-east are not unlike those in the north, the Rivelin Grit being separated from the Beacon Hill Flags by a shale parting with the late mut. β band at its base. This shale parting first becomes apparent near the top of Salter's Brook. South of Fiddlers Green its outcrop is over a quarter of a mile wide, and the shale appears to be over 100 ft. thick. The late mut. β band is poorly exposed in Cabin Clough, about 1,000 yards east-south-east of Fiddlers Green. A few feet of badly weathered rather sandy shale with *R. reticulatum* of late β type and lamellibranchs can be seen just above the Rivelin Grit. The shales form a ' slack ' along Hordron Bank, and reach the valley bottom near the foot of Mickleden. Here a bed of sandstone puts in just above the marine band. It forms a wide dip-slope on Midhope Moors, where it is hard and fine textured, but it dies out southwards near Pike Lowe. On the north-west side of the Barrow at Pike Lowe the section of these strata is roughly as follows :—

[1] *Trans. Manchester Geol. Soc.*, vol. xxv, 1897, pp. 184-191.

	Ft.
Compact fine-grained sandstone forming the hilltop at Pike Lowe (Beacon Hill Flags)	50+
Shales with a thin inconstant sandstone bed... ...	60
Sandstone, thickening to north and north-west ...	12
Sandy shale	2
Grey shale with goniatites in lower part—*R. reticulatum*, mut. β and early mut. γ	8
Sandstone (top of the Rivelin Grit)	—

The marine band is also exposed in the valley of the brook flowing northwards into the reservoir north-west of Upper Midhope (Thickwoods Brook), about 1,250 yards north of the Barrow, and in a more accessible condition in the western tributary of that brook (Calf Knoll Brook), 160 yards above its confluence with Thickwoods Brook.[1]

The section at the latter locality is:—

	Ft.
Blue micaceous mudstone	—
Sandstone	20
Black shale, sandy and barren at top, very fossiliferous below, with an inconstant line of calcareous bullions at the base. These contain uncrushed goniatites with petroleum inside them	8
Sandstone (top of the Rivelin Grit)	—

The most abundant fossils are *R. reticulatum*, mut. β and *Posidoniella rugata* J. W. Jackson. In all these exposures the goniatites are chiefly late forms of the β mutation.

The thin sandstone above the marine band seems to be present on the east side of Pike Lowe, but exposures are masked by local drift.

The marine band is exposed along the stream north of the farm (Ewden Lodge) on the west side of Ewden. The goniatites are the late β and early γ mutations of *R. reticulatum*; the bed lies close above the Rivelin Grit. The strata above the marine band are interrupted by the Ewden Fault, but it is probable that around here the Rivelin Grit is separated from the Beacon Hill Flags by quite 150 ft. of shales, the sandstone bed seen on Midhope Moors being absent.

The only other exposure of the late mut. β band is in the south-east corner of the area, about three-quarters of a mile south-east of Smallfield; here dark silty shales with *R. reticulatum*, late mut. β rest almost on the top of the Rivelin Grit. They are succeeded by a thick series of barren shales which crop out in a steep hillside capped by the Huddersfield White Rock. The Beacon Hill Flags have died out, and there are no indications of any sandstone beds in the shales 200 ft. or more thick between the Rivelin Grit and the White Rock.

2. *West of the Pennines.*—North-west of Delph these shales are not exposed, but their thickness cannot be much more than 30 ft.

Near Mossley marine shales with *R. reticulatum*, late mut. β overlie the Pule Hill Grit. The Beacon Hill Flags are absent in this district, the late β and γ bands being separated by only 25 ft. or so of shale. The sections of the strata between the Pule Hill Grit and the mut. β band in the two districts are as follows:—

[1] This exposure is separated by a fault from an exposure of the mut. γ band a few yards to the east, to be mentioned later.

North-west of Delph

	Ft.
Black platy shales with mut. γ etc. ... ... about	6
Ganister sandstone (Beacon Hill Flags)	30
Shales, not exposed	?30
Pule Hill Grit	—

Mossley

	Ft.
Black platy shales with mut. γ etc. ... ... about	6
Mudstone with mut. γ, including early forms	15
Calcareous ironstone	1
Shale	25
Grey mudstones with late mut. β and *Homoceras proteum* ...	6
Pule Hill Grit...	—

The exposures near Mossley are:—

Upper part of mut. γ bed—Mossley Sewage Works, about 450 yards south of Scout.

Lower part of mut. γ bed and late mut. β bed—South end of the tunnel at Scout, behind Scout Mill.

The late mut. β bed is not exposed south of here.

In the Glossop district the shales which crop out on both the north and south sides of the hilltop between Mouselow and Higher Dinting are probably at this horizon. On the north side their lower 30 ft. are exposed in a quarry face, and are seen to be barren. Their total thickness is probably about 60 ft. and they are succeeded by the sandstone capping the hilltop, apparently on the horizon of the Beacon Hill Flags.

The Beacon Hill Flags

1. *The main outcrop from north-west to south-east.*—The Beacon Hill Flags form a well-marked plateau on the eastern side of Pule Hill, being faulted down against the Pule Hill Grit which caps the hilltop (Fig. 7). They are exposed in the clough west-south-west of Marsden (above Clough Head), where they consist largely of fine-grained light coloured grit with many bands of hard ganister rock. Some of the latter are very massive and large weathered blocks of them occur over the greater part of the eastern slopes of Pule Hill. An attempt to work this ganister rock has been abandoned, probably owing to difficulties of transport.

On the south side of the valley north-east of Marsden the Beacon Hill Flags are well developed. Their outcrop is interrupted by several north-and-south faults. Throughout this area they can be divided into a lower series of thin-bedded flags and fine gritty sandstone, and an upper band of white ganister rock. The latter has been quarried in several places along the outcrop and is being worked at the present time east of Gate Head, about a mile east-north-east of Marsden Church. Here there are workings in both the lower flagstone group and the ganister rock. The former consists of about 20 ft. of fine white gritty sandstone separated from an overlying thin band of flags by about 1 ft. of shaly mudstone. The ganister rock has an average thickness of about 8 feet; it is massive and thick bedded and is overlain by a thin coal smut. About a mile west of Meltham Cop (around Holt Head) the ganister rock is underlain mainly by thin-bedded flagstones and tilestones which have been worked in the past in several places.

On the east side of the Wessenden valley the outcrop is marked by a feature running across the moors from Hind Hill on Binn Moor to the fault south-west of West Nab. Exposures are poor, but the rock is seen still to consist of a flaggy series capped by a massive bed of ganister rock. Towards West Nab the thickness decreases, being probably less than 40 ft.

The small capping of sandstone on the watershed at the Isle of Skye Hotel is apparently the Beacon Hill Flags. East of here the rock practically dies out, its position being indicated by only a faint feature in the hillside below the high-road, which can be followed with difficulty past Bradshaw.

The Beacon Hill Flags are well developed in an inlier south of Meltham, where they form a dip-slope north-west of Harden Green Plantation. The outcrop is limited eastwards by a fault running from Meltham southwards to Austonley. Throughout this area the Beacon Hill Flags consist of a lower series of flaggy grits and sandstones and an upper band of hard ganister rock; between the two is a seam of coal averaging nine inches in thickness, and known as the Lower Meltham Coal; it appears to be directly overlain by the massive ganister rock.

At the first road-bridge over the clough north of Harden Green Plantation a large disused quarry in the lower beds of the Beacon Hill Flags affords a section of about 20 ft. of laminated micaceous flagstones. These beds are also exposed along the floor of the clough to the west (Royd Edge Clough). The ganister rock is being worked along the north side of this clough, but the more easterly workings have been abandoned, largely owing to the heavy overburden. Quarrying is now proceeding 1,200 yards east-north-east of West Nab, where the section is as follows:—

	Ft.
8. Alternating sandy shales and thin flags, passing up gradually into the Huddersfield White Rock	—
7. Dark shaly mudstones	30
6. Dull black porous and earthy shale, crowded with goniatite impressions. The mut. γ band 9 in. to	1
5. Soft dark shaly mudstones, apparently unfossiliferous	6
4. Hard ganister rock	12
3. Lower Meltham Coal	0¾
2. Fireclay	1
1. Flaggy grit and sandstone	—

A similar section is seen in disused workings 450 yards to the north-east.

The Lower Meltham Coal is fairly constant in thickness and of good quality, but is not worked. The ganister rock has an average thickness of 12 ft., which occasionally decreases to 3 ft. It is very massive and generally devoid of bedding-planes. It has been proved all round the outcrop in this inlier,[1] though it varies considerably in thickness.

It was mentioned that the Beacon Hill Flags are practically absent along the hillside above Bradshaw (see p. 59), although well developed in den and south of Meltham. They are also absent along the outcrop between Bradshaw and Netherthong, although at a boring near Honley (see p. 182) they appear to come in again, while they are certainly present all over the country to the north. Their almost complete absence in the Holme and Heyden areas to the south shows that they die out rather suddenly along a line between Wessenden Head and Netherthong.

Around Holme and Heyden the marine shales with mut. γ generally rest on a variable thickness of the grey mudstones above the Heyden Rock. The top of the mudstones is often hardened into an iron-stained earthy sandstone. In Hey and Ramsden cloughs the Beacon Hill Flags appear to be present in the form of 10 ft. of sandstone at the former and 15 ft. of sandstone at the latter locality. In neither case has the sandstone a ganister-like top. The Beacon Hill Flags are not found in the other sections in this district. In Heyden Brook the top of the Heyden Rock is so close to the mut. γ bed as to leave no room for them.

Leaving the Heyden area we find on the east side of Withens Brook a thin sandstone bed, apparently the Beacon Hill Flags, appearing below the mut. γ band. It thickens and forms a wide shelf at the top of Salter's Brook, but appears to consist only of shaly sandstone. North of Saltersbrook Bridge it is again very thin, but to the east it swells out and forms the plateau over which runs the high-road between Saltersbrook Bridge and

[1] By the Meltham Silica Firebrick Company.

Fiddlers Green. The lower rather flaggy beds are exposed in the streams draining north into the upper reservoir in the valley south of Dunford Bridge. In this valley sandstones which are probably the Beacon Hill Flags are exposed on both sides of the lower reservoir, their base here descending to the water-level. A quarry on the west side of the reservoir (Windleden Quarry, see also p. 63) shows several feet of rough flaggy sandstone with worm-tracks on the bedding-planes. The stone breaks up into large slabs, which are used for roofing sheds, outhouses, etc. At the south end of the quarry the upper part of the sandstone is replaced laterally by shale, giving the appearance of an unconformity (see p. 63).

East of Lady Cross the outcrop runs along the north side of Loftshaw Beck to Cabin Clough. Here the flags form a well-marked feature and lie about 20 ft. below the mut. γ band. Their top is ganisterized and there is sometimes an overlying sandy fireclay. Between here and the Mickleden Fault the Beacon Hill Flags form the hilltop north of the Little Don River, their basal beds standing out in a bold escarpment (Long Moor Edge). Their ganisterized top is exposed in the stream to the north. They are thrown down into the side of the valley east of the fault, and are not exposed again on the north side of the river.

South of the Little Don the bed makes a sharp escarpment, which is crossed by the old pack-horse track (Cut Gate) three-quarters of a mile south of the river; here its lower part is exposed, and consists of massive hard fine-textured sandstone of a pale grey colour. At Calf Knoll, the prominent hill 1,100 yards to the east-south-east, the escarpment ends against the Hepworth-Ewden Fault. Here similar sandstone is exposed.

Just over a mile south-east of Calf Knoll is Pike Lowe (marked as Barrow on the one-inch map). Here a sloping plateau of Beacon Hill Flags terminates westwards in a sharp escarpment, which owing to its altitude is a conspicuous landmark. The plateau is almost an outlier and the sandstone is exposed along its steep western and southern edges. Around Pike Lowe the Beacon Hill Flags appear to be better developed than elsewhere in this part of the area. The shape of the ground indicates the probable existence of a thin shale parting, which separates a lower massive gritty sandstone from an upper compact fine-textured sandstone of great hardness. The latter is well exposed in a small crag at Pike Lowe Stones, 300 yards north-east of the Barrow. Both beds are pale grey in colour. The thickness exposed is probably at least 50 ft., but the top of the bed is not seen; it appears to have been ganisterized, as blocks of ganister are common in local drift deposits derived from the surface of the plateau (see p. 135).

The northerly dwindling of the feature on the east side of the plateau points to rapid thinning of the Beacon Hill Flags in a north-easterly direction. The top of the bed is seen in the stream nearly a mile north-east of the Barrow; it does not appear to be much ganisterized here, and consists of hard fine-grained sandstone. East of here the bed is faulted up, and forms a rib in the hillside below the escarpment of the White Rock. It appears to be less than half the thickness seen at Pike Lowe.

Along the north side of the Ewden valley the bed forms a distinct shelf in the hillside. Instead of the thick bed of hard pale sandstone seen at Calf Knoll and Pike Lowe, it consists of hardly 25 ft. of raggy sandstone with sandy shale beds. The thickness decreases to the east, so that the bed can only just be traced beyond the edge of the map. The change of facies appears to take place between Pike Lowe and a spot one and a quarter miles to the east-north-east, as shown by small sections north-west of Ewden.

On the south side of the Ewden valley there is a small thickness of sandstone and shale on the east side of the fault at Wightwizzle, but it appears to be at a lower horizon than the Beacon Hill Flags, which have probably died out in this direction. They appear to be absent in the hillside at the edge of the map, east-south-east of Smallfield.

2. *The Western Exposures.*—In the neighbourhood of Delph the Beacon Hill Flags crop out on both sides of the Tame between the village and Slackcote. They consist of about 30 ft. of ganister and hard ganister-like sandstone, which is exposed in a line of old quarries along the outcrop, 600 to 800 yards west of Delph Church; similar rock, almost a ganister, is exposed to a thickness of 12 ft. in old quarries 500 to 800 yards south-east of Slackcote. The ganister-like top of the bed, overlain by the mut. γ band is exposed in a small inlier just east of Slackcote; there is a similar exposure in the right bank of the Tame about 700 yards south-south-east of Slackcote. A hundred yards farther down the stream a section shows 10 ft. of ganister-like sandstone, resting on 3 in. of coal, resting on 4 ft. of ganister.

South of here the bed appears to be absent, although the thin sandstone in the Greenfield district and on Hollingworthhall Moor (see p. 56) may possibly represent it.

The Beacon Hill Flags may be represented north-west of Glossop by the sandstone capping the hill between Higher Dinting and Mouselow, and extending down to the fault at Dinting Station. Here flags with many shale partings are exposed in the railway-cutting.

The shales with the mut. γ Band

1. *The main outcrop from north-west to south-east.*—Around Marsden and Meltham there are a number of good exposures of the marine bed, from which fossils have been collected (p. 152). The best, under Royd Edge on Meltham Moor, is tabulated elsewhere (p. 60). The thickness of shale between Beacon Hill Flags and Huddersfield White Rock is in this area about 75 feet.

Along the eastern slopes of the Wessenden valley the shales between the Beacon Hill Flags and the Huddersfield White Rock give rise to a marked hollow or ' slack ' though no good sections occur owing to the thick covering of peat.

Around Harden, Upperthong and Netherthong the Beacon Hill Flags are absent, and the Heyden Rock and White Rock are separated only by 60 to 80 ft. of shales. The mut. γ marine band has been detected at two localities, in Robert Clough, near the Ford Inn, a quarter of a mile south-east of the 16th milestone from Barnsley at about 1,000 ft. above O. D. and again in Mark Bottoms Dike half a mile south of Netherthong Church at 525 ft. above O. D.; the latter is a very poor exposure, but a considerable number of fossils was obtained from the former (p. 151).

In the Holme district the Heyden Rock is not immediately succeeded by a marine band, the only one present before the White Rock is reached being that with mut. γ ; nor is there any sandstone of important thickness. In Ramsden Clough, from which mut. γ was first described (Bisat, W. S., *op. cit.*, p. 117) the following is the succession :—

	Ft.
White Rock	—
Shale and mudstone	80
Dark shale with marine fossils (mut. γ)	1
Coal smut	—
Shale with thin band of dwarf *Lingulae* at base ...	10
Sandstone ... ... about	10
Shale	50
Heyden Rock	—

In Rake Dike the exposure of the mut. γ band was noted by Mr. Bisat[1] "but only *Lingula mytiloides* and *Orbiculoidea nitida* were observed"; we have found the characteristic goniatite here, but the exposure is by no means easy of access; the succession here and along the slopes of Holme Moss to Ramsden Clough is similar to that given above. On the western side of the Cartworth valley the marine band was seen at about 875 ft. O. D. in Beaver Clough, Arrunden.

[1] *The Naturalist*, 1920, p. 351.

Around the edges of the White Rock plateau at Black Hill, west-south-west of Holme, the mut. γ band is exposed at the following localities :—

(*a*) Near the top of Hey Clough (200 yards south-east of the triangulation point on Black Dike Head). The section is :—

	Ft.
Huddersfield White Rock	40
Grey shales with sandy beds	35
Black shale with small specimens of *Lingula sp.* At about 9 ft. above the base is about 1 ft. of grey and black shale with the index-fossil, associated with cf. *Gastrioceras ? sigma* W. B. Wright	16
Grey sandy shale and mudstone hardened in the top 5 ft. to an earthy nodular-weathering sandstone ...	8
Sandstone with siltstone beds (? Beacon Hill Flags) about	15
Unexposed (? shale) ... ...15 to	20
Grit (Pule Hill Grit)	—

(*b*) At the top of Black Dike, the clough west of Hey Clough (100 yards north-west of the triangulation mark mentioned above).

The section here is less complete. A bed of black shale 6 in. thick, which has yielded the index fossil, *Gastrioceras cancellatum* Bisat, *G. ? sigma* W. B. Wright, and *Posidoniella sp.*, lies in the middle of about 20 ft. of black shale; this is succeeded by grey shale passing up into the White Rock. Beneath the black shale are several feet of grey shale with sandstone ribs, capped by 4 in. of ferruginous sandstone.

(*c*) Near the top of Crowden Little Brook (300 yards south-south-west of the triangulation mark at 1,888 ft.).

Here a partially exposed section shows 15 ft. of dark shale with the usual goniatites at three or more different levels. Beneath the black shale is at least 20 ft. of grey silty mudstone and shale, the top 6 ft. being hardened to an earthy sandstone.

(*d*) Heyden Brook, near the junction of the two head-streams at Heyden Head.

Here the marine bed is very fossiliferous. From the top of the Heyden Rock there is about 25 ft. of sandy mudstone followed by a thin rib of sandstone 6 ft. thick; the black marine shales rest directly on this rock; the base of the White Rock is about 60 ft. higher.

The top of the 6-ft. sandstone rib in this section, and of the earthy and ferruginous sandstones of the three preceding sections, marks, if not a land surface, at least an abrupt break in the conditions of sedimentation.

The mut. γ bed is not exposed in the country between Upper Heyden and Salter's Brook, but its position can be inferred from the outcrop of the overlying White Rock which forms the escarpments of Britland Edge and Withens Edge. The band is well exposed on the north side of the clough running north-east from Wike Head (Dearden Clough), but there is no mention of a marine bed in this position in the section of Nos. 4 and 5 shafts of Woodhead Tunnel. In the quarry 800 yards south-south-west of Dunford Bridge Station the marine bed is exposed over a distance of about 100 yards. It occurs as a band about 3 ft. thick characterized by a basal dark layer, and is about 5 ft. up in a bed of blue clay shale. The top of the underlying sediments is stained slightly ocreous and shows signs of having been a land surface. There is a slight difference in the dip of the two sets of deposits, and whereas at the north end of the quarry the blue shale rests directly on sandstone (the Beacon Hill Flags, see p. 61) at the north-west end about 20 ft. of sandy shale intervenes between the sandstone and the blue shale.

The bed is exposed at two other localities near Dunford Bridge :—

(1) On the south side of the reservoir east of Dunford Bridge and just about top water level. Here a band of highly micaceous shale about 2 in. thick occurs at the base of the bed of blue shale. It contains numerous

small *Lingulae* and occasional fragmentary goniatites. A few fish scales were noted in the material about 3 ft. above the band. It is possible that the true mut. γ band occurs a few feet higher in the sequence, but the exposure is obscured by landslip. In some instances, as already noted, both the *Lingula* band and the mut. γ band occur together.

(2) Near the foot of Long Grain, just over half a mile east of Dunford Bridge, and just above an old bridge over the stream. At this locality the best material occurs on a small dump on the west side of the stream and immediately above the bridge. The material here yields a number of limestone nodules containing uncrushed goniatites of the *sigma* type. At this locality the overlying shales have yielded a few fish scales.

In the Dunford Bridge area the marine band is succeeded by blue shales with occasional fish scales, which pass upwards into sandy shale with flaggy sandstone followed by the White Rock. In this area and to the south-east the marine band usually lies close above the Beacon Hill Flags.

In the upper part of the Little Don valley the bed is exposed at the following localities:—

(*a*) Cabin Clough (p. 61), 970 yards east of the end of the old road at Fiddlers Green. This is a good exposure.

(*b*) Long Moor Clough, just over a mile east of the same point at Fiddlers Green.

(*c*) A poor exposure in the bluff above the farm a mile south-south-east of the 5th milestone from Penistone on the Woodhead road.

(*d*) The foot of Long Moor Clough, nearly a mile south-east of the above milestone.

(*e*) Hingcliff Scar, on the right bank of the Little Don, about 300 yards north-east of (*d*). Here more than 8 ft. of pale purple highly fossiliferous shale, with a sandy layer near the top, occurs in the middle of a thick shale bed (40 ft. thick). It contains an abundant fauna, including in addition to cephalopods many brachiopods and lamellibranchs.

On Midhope Moors the mut. γ band lies near the bottom of 60 to 70 ft. of shale which separates the Beacon Hill Flags from the White Rock. There are good exposures at two localities:—

(*a*) Thickwoods Brook, three-quarters of a mile south-west of Upper Midhope, at the foot of Calf Knoll Brook. The section is similar to that in Shaw Clough (see below) but is less complete. It is partly disturbed by the Hepworth-Ewden Fault, which throws the mut. γ bed against the late mut. β bed in Calf Knoll Brook (p. 58).

(*b*) Shaw Clough, nearly a mile north-east of the Barrow (Pike Lowe). The marine bed is clearly exposed along the right bank of the stream. The section is:—

	Ft.
Sandstone almost *in situ* (White Rock)	—
Grey mudstone with sandstone ribs ... ... about	20
Highly fissile black shale with tabular ironstone nodules	24
Dark grey and black shale full of fossils ... about	3
Dark grey shale with fossils in the upper part and ferruginous concretions in the lower 7 feet... ...	18
Sandstone (Beacon Hill Flags)	—

Fossils are abundant and well preserved. Both here and at Hingcliff Scar *Gastrioceras? sigma* occurs in the upper part of the band.

The marine band is not exposed along the north side of the Ewden valley, but the shale between the White Rock and Beacon Hill Flags appears to maintain much the same thickness.

On the south side of the Ewden valley the mut. γ band lies 20 to 30 ft. below the White Rock, and overlies a great thickness of unexposed shale which apparently extends down to the Rivelin Grit (see p. 58). It is not seen

except just beyond the edge of the map. There are uncertain indications of a bed of ganister below the marine bed here, possibly of workable thickness.

2. *The Western Areas.*—North-west of Delph the marine band is seen at three localities (see p. 152).

In Slackcote Lane, 250 yards north-east of Slackcote, the ganister top of the Beacon Hill Flags is succeeded by 15 ft. of dark shales with *Lingula sp.* 4 ft. above and the index-fossil 6 ft. above their base. *Gastrioceras? sigma* also occurs rarely in the associated shales.

South of Greenfield the Beacon Hill Flags, as already mentioned, cannot be distinguished, and shales extend from the Pule Hill Grit to the Huddersfield White Rock. They are exposed at the south end of the tunnel at Scout and at Mossley Sewage Works (pp. 58, 59). The marine bed consists of 22 ft. of shale. The upper 6 ft. is black and platy, and is comparable with the Slackcote sections. It has yielded the index-fossil and *Gastrioceras? sigma.* The lower 15 ft. is a mudstone containing scattered specimens of the index-fossil, with forms transitional to late mut. β at the base.

The barren shales above the mut. γ band are exposed in the cutting at Scout. They are about 200 ft. thick and consist of grey mudstones, passing down into dark shale in the lower part.

In the Hattersley district the presence of the complete shale series is inferred between Mile-end House and Shopwell where the solid rocks are obscured by drift.

The Huddersfield White Rock

1. *The Northern Area.*—The Huddersfield White Rock forms a broad flat area on Deer Hill Moor east of Marsden with a prominent scarp feature facing northwards and overlooking the Colne valley. There is a small group of disused quarries at Burnt Hill showing yellow micaceous flaggy sandstone.

A narrow faulted strip of Huddersfield White Rock also occurs on the summit of Binn Moor, on the eastern side of the Wessenden valley. By far the largest area, however, underlain by the Huddersfield White Rock is the upland plateau with the gentle easterly slope on which the town of Meltham is built. This area extends continuously from Deer Hill and Meltham moors right to the east of the town of Meltham.

The Huddersfield White Rock occurs here in a broad shallow syncline in the centre of which the town of Meltham is situated. To the north the White Rock forms a prominent escarpment feature at White Reaps and Spring Head overlooking the Colne valley with a south-easterly dip. To the south-west of Meltham the White Rock forms a prominent scarp feature at Banister and Royd Edges, the beds here having a north-easterly dip.

On Black Moor Top and at Meltham Edge and Spring Head to the north-west of Meltham, and also at Helme, there are several small disused quarries in the Huddersfield White Rock, here a whitish-yellow flaggy grit or sandstone with occasional sandy shale partings. In a small quarry alongside the Colne and Holme Hospital the White Rock largely consists of yellow ganisteroid grit. A fine series of natural sections in the Huddersfield White Rock is seen practically along the whole course of the Brow Grains Beck or Meltham Dike which drains eastward from Deer Hill and West Nab moors through the town of Meltham. Here it varies from a massive thick-bedded flaggy grit to fine-grained flaggy sandstone with occasional thin shale partings. Sections also occur in the same beds at Meltham railway station and in cuttings alongside the Meltham branch railway.

In the little stream-course which drains southwards from Helme towards Hall Dike there is a very picturesque waterfall, locally known as the Dolly Folly Waterfall, about 500 yards due north of St. James Church, Meltham Mills. Here a face of upwards of 30 ft. of rather massive and very obliquely bedded light yellow and fine-grained grit (the Huddersfield White Rock) is faulted against black shales and mudstones across the course of the stream and gives rise to the waterfall.

The floor of Hall Dike practically along its whole course from Meltham to Healey Mills and Netherton Beck is along the upper surface of the Huddersfield White Rock. In several places its upper surface is exposed; it consists of hard whitish or yellowish ganister rock, and is overlain by fireclay and the Upper Meltham Coal.

Along Banister and Royd Edges, to the south of Meltham, the Huddersfield White Rock has been worked in several quarries, all of which are now standing. The material worked was a fine-grained whitish or yellowish freestone. In some places the bed of freestone is over 30 ft. thick, though thin flaggy layers and shaly partings are not infrequent throughout the greater thickness of the rock. The following is a measured section in Royd Edge Main Quarry, 1,150 yards south-west of Meltham Parish Church :—

	Ft.
3. Rather hard false-bedded flaggy sandstone (not worked)	10
2. Thinly laminated flaggy sandy shale with lenticular flaggy sandstone bands	3
1. Massive thick-bedded light yellow fine-grained sandstone, with numerous 'mare-balls' (worked)	30

Around Thick Hollins, Wilshaw and Netherthong there are several small disused quarries in the Huddersfield White Rock. On Thick Hollins Moor there are several quarries which show upwards of 20 ft. of strongly cross-bedded yellowish and flaggy gritty sandstone with occasional soft sandy incoherent patches. The old quarries around Wilshaw exhibit similar features.

The village of Netherthong is built on the scarp of the Huddersfield White Rock, and the rock is exposed alongside the lanes in the village and also along the course of the Dean Brook. There is also a small disused quarry near the Huddersfield Union Workhouse at Deanhouse.

In this district the Huddersfield White Rock is almost invariably a light yellowish thinly laminated gritty sandstone, with an occasional thicker and more massive bed.

One thousand yards north-east of Netherthong Parish Church there is a large disused quarry in the Huddersfield White Rock alongside Calf Hill Wood. Here the beds are more massive than usual, though shaly lenticular patches are not infrequent and apparently render it unprofitable to work as a building stone.

South and west of West Nab the rock contains a parting of grey sandy shale 20 ft. or more thick; the beds above this are sandstone with some sandy shale; the ganister lies 10 ft. above the top of the sandstone and the Upper Meltham Coal is probably present. Near the Isle of Skye Hotel, Wessenden Head, there are small excavations in raggy sandstone in the scarp above the high-road.

North of Bradshaw the White Rock is quarried on the north side of the Greenfield road; up to 30 ft. of fine micaceous somewhat current-bedded sandstone is seen. Near the Ford Inn, on the same road rather less than 16 miles from Wakefield, the top of the rock is shown by the presence of two small outliers of the Upper Meltham Coal and overlying shale; a boring shows the thickness of the rock to be about 56 ft. (p. 69).

Eastwards from here the White Rock is overlain by about 25 ft. of shale with the Upper Meltham Coal at the base and the Cancellatum marine band in the middle, above which is a sandstone (p. 70). From the Ford Inn to the fault passing north-east through Wolfstones the ground is a dip-slope formed by the top surface of the rock, as shown by the presence of ganister; at Wolfstones Gardens, between Wolfstones and Upperthong, the ganister has been worked. At Binns Wood Quarries, half a mile west of Holmfirth Parish Church, 40 ft. of strongly current-bedded coarse sandstone or fine flaggy grit is seen.

Along the ridge between the Holme and the Ribble valleys (Cartworth lies in the latter) the White Rock has been much quarried; the deepest section seen is about 40 ft. The rock is usually thick bedded and of medium grain; the upper part is often current bedded and the value of the lower part sometimes spoilt by pillow structures and ' mare-balls.' East of the Ribble the rock is similar; a disused quarry at Gully shows up to 50 ft. of it.

2. *The Central Mass.*—The plateau of Holme Moss rises very gently westward to 1,908 ft. at Black Hill and is fringed by an abrupt escarpment on the north and west.

The lower beds, seen to the extent of 40 ft. or more, consist of thin-bedded sandstone with flaggy beds. The sandstone passes more or less gradually into the underlying shales.

Springs issue from the base at the top of Hey Clough and Crowden Little Brook.

Along the road over Holme Moss the rock has been quarried to a small extent for walling and road metal; over the greater part of the area the peat conceals the rock except at the margins where flaggy basal beds are visible in the stream-courses; but immediately south of the east-and-west fault the ganister at the top can be traced. In Ramsden Clough nearly the whole thickness is exposed at Ramsden Rocks on the west and Tickle Scar on the east. Mudstone partings are prominent in the lower part. At Britland Edge Hill on the south side there is a sharp feature but no exposure. At Grains Edge near the head of the Little Don the feature is due to the east-and-west fault just mentioned.

South of this fault the base of the White Rock is marked by the escarpments of Withens Edge and Dead Edge. The open moorland on the hilltops dips gently north-east and over much of the ground lies on a dip-slope formed by the weathered top of the White Rock. A good view of these features can be obtained from Cook's Study.

South of the Don the White Rock forms cappings on Upper Dead Edge and Windleden Edge, where it has been quarried. Across Windleden it occupies an area of about two square miles on Thurlstone Moor; it is cut off on the east by faulting. The bed is also exposed on both sides of the Little Don near Hingcliff Hill, where it forms a well-marked feature.

3. *The South-eastern Area.*—On the west side of Langsett Reservoir the outcrop is interrupted for a short distance by a trough-fault, part of the Hepworth-Ewden disturbance. It then runs across the northern part of Midhope Moors, forming a wide dip-slope terminating southwards in an escarpment. Followed eastwards the escarpment becomes very prominent above Ewden, forming the sharp northern edge of the valley, the side of which falls steeply to Ewden Beck, 400 ft. below. Just east of here the outcrop rapidly narrows, the Rough Rock now forming the edge of the Ewden valley, and the wide heather-covered dip-slope is reduced to a shelf less than 200 yards wide, running along the side of the valley to the edge of the map. The thickness along this part of its outcrop is between 70 and 100 ft.

On Midhope Moors a shale parting over 30 ft. thick is present in the lower part of the rock. It is exposed in the valleys of the two streams draining into Langsett and Midhope reservoirs, the lower leaf of sandstone forming a subsidiary escarpment. This parting dies out eastwards towards Ewden, and is also missing on the west side of the Hepworth-Ewden fault-system.

The nature of the rock gradually changes along the strike. On Midhope Moors it is a rough flaggy sandstone, much divided by sandy shale partings, as well as by the thick shale just mentioned. Above Ewden it is a fine-grained, rather flaggy sandstone, and has lost much of the interbedded shale. Farther east in the Ewden valley it is a rather massive well-bedded sandstone. It is a rock of similar nature on the other side of the Ewden valley, south-east of Wightwizzle, where it forms a gently sloping plateau

with a steep northern scarp-face. The north-easterly dip is causing the rock to slip over the underlying shales, and great masses of slipped material cover the slopes below. The western part of the plateau has been reduced by this process of denudation to a tongue of high ground only 200 yards wide. The thickness of the White Rock here is somewhat less than 100 ft. A bed of ganister lies either on top or just above it.

4. *The Western Area.*—Here the rock is also known as the Holcombe Brook Grit, the name in general use in Lancashire.

North-west of Delph is crops out in a narrow shelf along the south-west side of the Tame. There is also a small outlier north-east of Slackcote. Small exposures show that it consists chiefly of hard white sandstone with some flaggy beds. It is about 30 ft. thick, occasionally less.

The top is a ganister and is overlain by the Upper Meltham Coal (below). There are obscure indications of a coal seam being present in the midst of the rock.

West of Greenfield the bed expands, but its full thickness is not known. A quarry about 200 yards north-west of Grasscroft shows about 15 ft. of flagstone and ganister-like sandstones, coarse towards the base, with a thin mudstone parting, resting on 3 in. of coaly shale, on 3 ft. of fireclay and mudstone.

South of Mossley the White Rock has decreased in thickness to about 20 ft. The topmost 15 ft., consisting of grit, is exposed 430 yards south-west of Mossley Station. It is further decreased to about 15 ft. in the cutting at the south end of the tunnel at Scout, where the upper part is fine grey sandstone. It expands again near Heyrod, where it is a strong white grit or sandstone with shaly bedding-planes in the upper part.

In the stream (Acres Brook) just over half a mile west-north-west of Stalyhill 30 ft. of fine brown sandstone was seen at this horizon.

South of this brook the bed cannot be traced, owing to the thick covering of drift.

The Rough Rock Series

The Upper Meltham Coal.—The Huddersfield White Rock is overlain by a prominent bed of fireclay and a thin seam of coal which has been termed the Upper Meltham Coal. In several places this coal has been worked on a small scale.

Small disused crop-workings occur 800 yards west of Deerhill Reservoir (on the moor between Marsden and Meltham), but they are completely overgrown and no section is now visible.

During the construction of Blackmoorfoot Reservoir to the west of South Crosland, the Upper Meltham Coal was exposed and the following section was observed:—

	Ft.	In.
Black shale	10	0
Coal	0	9
Fireclay	0	2
Coal	1	4
Hard ganister rock ... ...½ to	0	1
Fireclay	5	6
Flaggy sandstone (Huddersfield White Rock) ...	—	—

Meltham Cop consists of an outlier of Rough Rock Flags resting on a thick shale series and all around its base the Upper Meltham Coal crops out. The coal was exposed at the south-western corner of Meltham Cop during the construction of the Blackmoorfoot water conduit and disused workings occur in Orange Wood 400 yards north of Helme Church. These end abruptly on the eastern edge of the wood owing to an important north-and-south fault which brings the coal to a much lower level to the east of the wood.

At the base of the plateau known as Shooters Nab and West Nab, about a mile and a half due west of Meltham the crop of the Upper Meltham Coal can be traced continuously from Deerhill Reservoir past Brow Grains to the south of West Nab on Meltham Moor.

Alongside Brow Grains and for a distance of some eight hundred yards to the south towards West Nab there is a series of disused crop-workings in this coal. At Brow Grains Road there are in addition some disused shallow shafts stated to be about 40 ft. deep and here the coal was said to range from 2 to 3 ft. in thickness and contain several thin dirt partings.

At Mill Moor, 300 yards south-west of Meltham railway station there is a small faulted outlier of the beds overlying the Huddersfield White Rock with the Upper Meltham Coal at the base. The total area of this outlier is roughly five thousand square yards. The coal was worked here about fifteen years ago from a shaft (known as Greens End Mine) about 24 ft. deep. The full section of the seam was as follows :—

		Ft.	In.
	Soft black shale	—	—
Upper Meltham Coal	Coal (left in)	1	0
	Coal	1	0
	Shale	0	4
	Coal and clay	1	9
	Good fireclay (worked)...	3	6
	Ganisterized yellow sandstone...	—	—

The coal had an average dip of 1 in 25 in a northerly direction, and the workings were limited in an easterly direction by an important fault running north-west and south-east. To the south of Crosland Edge the Upper Meltham Coal is well exposed at the Dolly Folly Waterfall.

In the lower part of Honley Wood there are several disused and overgrown shafts sunk originally to work this seam, though no particulars are available. There are also evidences of old workings in the Upper Meltham Coal along the sides of Hall Dike to the north-west of Scot Gate, Honley. Here there is a disused overgrown shaft, probably not very deep.

The Upper Meltham Coal crops out in Windy Bank Wood, Thick Hollins; it has been worked on a small scale here, and also to the east of Meltham Mills Reservoir between Wood Nook and Wilshaw. In the latter locality it is much cut up by small faults. A section exposed during the recent re-survey of the district showed that the coal was about 9 inches thick and rested on a good bed of fireclay and hard ganister rock with rootlets; a boring near the Ford Inn showed the thickness to be 8 in. (p. 66). The coal was also seen in the bed of the Dean Brook between Oldfield and Netherthong though it does not appear to have been worked in this district. At Wolfstones Gardens (p. 66) the coal appears to be too thin to be worked. On the east side of the Cartworth valley it can be traced as far south as Longley, but is again thin.

Farther south the Upper Meltham Coal and underlying ganister is seen in Reaps Clough behind Cook's Study, where it is only 3 in. thick. An exposure in a stream near Elysium, a quarter of a mile north of Hades, suggests that there may be two thin coals separated by sandy fireclay. The coal is also seen in the upper part of the Don valley near Snailsden House. In that of the Little Don the coal is thicker; in Wind Hill Wood the section was: coal 10 in., bastard ganister 10 in. It was also seen during the construction of Midhope Reservoir.

On the west the Upper Meltham or Holcombe Brook Coal is everywhere present. It has been worked in recent years 800 yards north-west of Denshaw and from an adit about the same distance west-south-west of Delph Church. Here it is 33 in. thick and rests on the ganister-like top of the White Rock. Near Mossley an adit 450 yards south-west of the station shows 3 ft. of fireclay beneath the coal. There are also signs of old workings in Acres Brook, south-south-east of Stalybridge.

South of the Etherow valley the outcrop of the Simmondley Coal runs southwards from the Dinting Vale fault just east of Brookfield, passing to the east of Gamesley. The coal has been worked from a shaft 350 yards south-south-east of Gamesley cross-roads. *G. cancellatum* occurs in the material on the tip.

The Shales below the Rough Rock.—These beds everywhere contain the two marine bands with *Gastrioceras cancellatum* and *G. cumbriense*. In the north they are up to 150 ft. thick and consist entirely of shale; below West Nab they are 120 to 130 ft.

Between the Ford Inn and Wolfstones there is a well-marked escarpment of the shale above the White Rock, capped by sandstone. The shale is dark and papery, the lowest beds showing frequent stellate rusty spots. The Cancellatum Band occurs about 20 ft. above the White Rock, and the total thickness of shale to the base of the sandstone is about 30 ft.

The rock above the Cancellatum Band forms a considerable dip-slope from the fault along the east side of Harden Green Plantation to Wolfstones; a small quarry shows 10 ft. of flaggy somewhat current-bedded sandstone, and the total thickness is probably not much more. Some 30 to 40 ft. of shale separates it from the base of the Rough Rock at Wolfstones Height.

In the scarp overlooking Holmfirth the Cancellatum Band is exposed at the roadside 200 yards south-east of the station.

Almost the whole thickness of the shales between the White Rock and the Rough Rock is seen in the valley of the Dean Dike from Boshaw Whams Reservoir near Daisy Lee to the fault by Hepworth Church. The Cancellatum Band is frequently exposed in both banks; near Hepworth Bridge it is 22 ft. above the stream and the White Rock must therefore be approximately at stream level, though not visible.

The shales are well exposed near Cook's Study and in Harden Clough below Snailsden Reservoir. Two marine bands are seen in a small stream north-east of Cook's Study, the lower one below the road and the upper one above. The lower one is also seen at several places in Reaps Dyke, and in the cliff, Reaps Scar, at the top end of Snailsden Reservoir. The lower band lies some 20 ft. above the Upper Meltham Coal. Exposures of a marine bed are also seen in landslip materials at Linshaw Scar and in Harden Clough below Snailsden Reservoir. East from here there are no exposures of the marine bed between Dunford Bridge and Carlecotes, nor at the head of Langsett Reservoir, though the underlying Upper Meltham Coal was seen before the reservoir was made.

In the valley of the Little Don near Hingcliff Hill about 30 ft. of blue shale intervenes between the top of the White Rock and a bed of shaly sandstone which caps the hill. A sandstone in about the same position is seen in the steep bank below Swinden Lodge where it is succeeded by 50 ft. or so of shale before the base of the Rough Rock is reached. The same sandstone is also seen in the cutting on the light railway on the east side of Cat Clough. The exact relations of this sandstone are not known; it is most probably a local development of the sandstone near Wolfstones mentioned above.

In the trough west of Langsett Reservoir the shales are not exposed. They form the steep bank below the Rough Rock escarpment which runs past Upper Midhope and Wind Hill Wood, and along the north side of the Ewden valley to the edge of the map. Here they are 120 to 150 ft. thick.

At Low Moor, south of Upper Midhope, they spread northwards beyond the foot of the escarpment. A feature here indicates the presence of a hard bed, probably of sandstone, not more than 20 ft. thick, with its base about 30 ft. above the top of the White Rock. This may be an attenuated form of the bed which caps Hingcliff Hill. It dies away to the east.

The steep bank on the east side of Midhope Reservoir shows the following section when the water is low; it extends down to within a few feet of the White Rock.

	Ft.
Sandstone (Rough Rock)	12
Rather sandy grey shale with occasional *Carbonicola* (A *Carbonicola* band[1] about 24 feet down)... ...	30
Dark blue shale	18
Black shale with ironstone nodules	8
Grey clay	0½
Grey shale with ironstone nodules	15
Beds not exposed (the *G. cumbriense* bed probably occurs here)	30
Black shale with ironstone nodules and beds of soft grey shale. Poorly exposed in lower part (the *G. cancellatum* bed probably occurs here)	20

Although neither of the two marine bands are seen in this section, black shale with poorly preserved goniatites is exposed in the reservoir bank about 300 yards to the south-east. This is probably the *G. cancellatum* band, although the fossils cannot be identified.

There are exposures in shales along the stream running north through Wind Hill Wood. A marine bed near the base of the series, the Cancellatum Band, yielded a number of fossils (p. 155).

Along the side of the Ewden valley the series is not well exposed. A feature formed probably by a thin sandstone bed reappears here at about the horizon of the Hingcliff Hill rock, some 30 to 50 ft. above the White Rock.

West of the Pennines.—The outcrop of these shales is seen near Delph, Denshaw, Greenfield, Mossley and Stalybridge. Of the two marine beds present in these shales in other areas, only the Cancellatum Bed is seen and that only in one section near Stalybridge, owing to poorness of exposures.

South of Mossley the shales appear to be at least 250 ft. thick. At the south end of the tunnel at Scout the lower 40 ft. of the shales, dark in colour, are partially exposed at the top of the cutting. A search failed to reveal the Cancellatum Bed, but there is little doubt that it is here present.

South of Scout the only good exposure is in Acres Brook, south-south-east of Stalybridge; the Cancellatum Bed is seen about 35 feet above the Upper Meltham Coal. The exposure consists of 2 ft. of black shale with *Gastrioceras cancellatum* and *Reticuloceras reticulatum,* mut. γ, *Pterinopecten sp.* and *Posidonomya sp.*

South of the brook the shales are obscured by thick boulder-clay.

The Rough Rock and the Rough Rock Flags.—In the north the Rough Rock gives rise to a bold escarpment facing westward, while its upper surface forms a very uniform moorland and plateau surface sloping gently eastwards. In this area it can usually be subdivided into the Rough Rock proper and the underlying Rough Rock Flags; there is no very definite line of subdivision between the two and in some places the latter appear to be absent altogether, and flaggy layers do occasionally occur within the main mass of the Rough Rock itself.

To the south-east of Marsden and about a mile to the west of Meltham an extensive outlier of the Rough Rock forms an elevated plateau and conspicuous scenic feature known as Deer Hill Moss or Scout Moss.

To the north, east and south the edge of this plateau forms a marked escarpment consisting of crags and stacks of massive grit overlying the softer shales. The northern scarp-face overlooking the Colne valley is known as Shooters Nab or Deer Hill while that to the south of Meltham Moor is known as West Nab. This prominent feature forms a well-defined landmark readily visible from any elevated point in the Coal Measure tracts twelve miles to the east; when viewed from this direction the top of the plateau is seen to dip away gently southwards from Shooters Nab on the north, and to dip gently northwards from West Nab on the south. This is

[1] Containing *Carbonicola* cf. *recta* Trueman. D. A. Wray and A. E. Trueman, 'Summary of Progress' for 1930, Part iii (*Mem. Geol. Surv.*), 1931, p. 71.

due to the general dip of the beds, the whole outlier consisting of a broad shallow syncline with its axis running practically east and west midway between Shooters Nab and West Nab (p. 122).

Along the northern part of this outlier about 20 ft. of Rough Rock Flags underlie the Rough Rock proper but to the south they are not recognizable as a separate subdivision.

Practically the whole of the northern scarp-face at Shooters Nab consists of a line of disused quarries. These show thick-bedded and massive grit with occasional thin lenticular shale partings. In some of the quarries there are also numerous large incoherent ferruginous and sandy masses of spherical form locally known as 'mare-balls.' In some cases these appear to be confined to definite horizons in the stone. An old quarry near the north-western corner of the hill shows the massive gritstone resting on thinly laminated and micaceous flaggy sandstone. Behind the Deerhill Reservoir a north-and-south fault can be clearly located in the escarpment by the relative positions of the quarries on either side of it. At the north-eastern end of the hill the stone has been quarried for reservoir embankment construction in recent years; it is very massive and thick-bedded and some beds which contain large quartz pebbles pass into a conglomerate in places.

At its southern end the Rough Rock plateau reaches its greatest altitude, and terminates in the escarpment of West Nab. Here large blocks of pebbly grit, showing the effects of wind erosion, lie scattered over the hilltop. A 'Rocking Stone' (now displaced) is marked on the six-inch map about 250 yards west-north-west of West Nab.

One mile to the north of Meltham there is a prominent isolated hill known as Meltham Cop. This is formed by a thin capping or small outlier of Rough Rock Flags resting on a thick mass of shales and mudstones. Only fine shaly flags are represented at the summit of the hill and the Rough Rock proper appears to be absent. Half a mile to the east the main mass of the Rough Rock forms a prominent escarpment at Crosland Edge. From here it forms an elevated sandy plateau stretching away past South Crosland towards the town of Huddersfield. Large disused quarries occur at Crosland Bank to the south of South Crosland and also alongside Blackmoorfoot Reservoir at Crosland Edge. Here the stone is a yellowish rather massive even-grained grit.

The Rough Rock forms a sandy plateau on Honley Moor some two square miles in extent with an escarpment to the west and south, and with a fairly uniform north-easterly dip-slope towards the village of Honley and the Holme valley.

There are several large quarries in the Rough Rock at the western end of Honley Wood and also at Knowl Top, the feature formed by that grit to the north of Thick Hollins. The several quarries on the northern slopes of Knowl Top show 25 to 30 ft. of rather massive false-bedded grit with lenticular shaly partings and bands of incoherent sand. In this area the lowest beds are distinctly flaggy but there is no definite line of subdivision between these and the overlying more massive grit.

There is a large disused quarry in Slate Pits Wood, 900 yards east of Meltham Mills Parish Church; although the beds appear to be on a higher horizon than in the above-mentioned quarries, the Rough Rock here mainly consists of thinly-laminated flaggy grit. The beds are very strongly false bedded.

At the north-eastern end of Honley Wood there are large quarries at Scot Gate, where the Rough Rock is a massive-bedded and very even-grained freestone. These quarries have been worked for many years for building stone and other purposes, and occasionally the stone has been sent to distant centres. York Castle is in part built of Scotgate stone.

In the town of Honley there is an excellent natural exposure of the Rough Rock at the Tor Rocks alongside the steep hollow known as Thirstin. Here the grit is massive and thick bedded, with occasional thin flaggy bands.

To the east of Wilshaw the Rough Rock forms a prominent feature at Swinny Knoll, and eastwards from this point it gives rise to a marked escarpment at Oldfield as far as Hagg Leys. In this area the lower part of the Rough Rock is distinctly flaggy and can be mapped separately from the overlying more massive grit. Alongside the steep lane leading from Netherthong to Upper Oldfield the dark and grey shaly mudstones overlying the Upper Meltham Coal pass upwards into fine flaggy shales which are in turn overlain by thin flags and flaggy grit. Approaching the hamlet of Upper Oldfield the more massive Rough Rock is seen alongside the road.

On Honley Moor and around Wood Nook the Rough Rock forms a sandy plateau with a uniform easterly slope. Owing to the relative thinness of the soil the land is largely moorland, being covered by heather and patches of bracken. There are several small quarries in which the Rough Rock is seen to be massive and thick bedded, while occasional bands of a conglomeratic nature also occur. The little outlier at Wolfstones consists of coarse grit and conglomerate; it is false bedded and contains streaks of coal; some 10 to 12 ft. is seen in the quarry.

The Rough Rock crops out in the Holme valley from the north of Honley southwards past Brockholes to Thongs Bridge and New Mill. Where the Hall Dike Brook enters the Holme valley to the north of Honley it forms a pretty wooded gorge known as Mag-a-dale.

Around Brockholes and in Hagg Wood there are several large quarries in the Rough Rock, while the grit also forms a series of crags along both sides of the Holme valley between Brockholes and Mytholm Bridge.

Around Brockholes Church and at the Robin Rocks, Brockholes, about 30 to 40 ft. of rather massive false-bedded grit is exposed. In Hagg Wood the grit is coarse grained and massive but somewhat incoherent owing to the decomposition of the large amount of felspar it contains. It is here being worked for sand.

At Scar End, 900 yards south of Brockholes railway station, there is a prominent east-west fault with a large downthrow to the south. The line of the fault is well seen in the railway-cutting at Scar End where Lower Coal Measures shales are faulted against massive Rough Rock.

Alongside the River Holme at Scar End the massive Rough Rock is underlain by sandy shale with bands of flagstone.

Along the banks of the River Holme at Thongs Bridge the Rough Rock forms crags, while an excellent section of the grit is seen in the railway-cutting at Thongsbridge Station. Several sections in the Rough Rock are also to be seen along the banks of New Mill Beck between Mytholm Bridge and Hepworth. At Sinking Wood there are several east-and-west faults with a small throw. One of these is well seen in the roadway close to Sinking Wood Nook.

East of Holmfirth Station the Rough Rock forms Wooldale Cliff, in which some 30 ft. of coarse pebbly grit is exposed.

Between Scholes and Longley are many old quarries showing up to 20 ft. of current-bedded grit; sections around Hepworth show coarse grit with seams of pebbles from the base to the top of the division.

Farther south the Rough Rock Flags are well developed on the ridge on the north side of Harden Clough and also in an outlier on the south side; this caps the ridge which terminates in Snailsden Pike End at the west. The beds have been worked on a large scale for a long time and are now almost wrought out.

A striking feature of these two outcrops is that at numerous localities the flags are vertical or contorted in the quarries on the hilltop, but the underlying flags where seen in the stream on both sides have the normal dip of the country, even at localities which are directly on a line with the strike of the upturned flags. The flags are current bedded, and possibly the upturning is due to movements such as deltaic slip soon after its deposition. The Rough Rock Flags can be traced down the Don valley to Hazlehead, but farther south they either die out or are replaced by sandy shale on the side of Langsett Reservoir.

In the quarries at Hade Edge and Low Edge, between Holmfirth and Dunford Bridge, about 15 or 20 ft. of sandstone and sandy shale with a dirty coal at the top intervene between the Flags and the Rough Rock. The coal which is underlain by a shaly fireclay varies from 1 to 2 ft. in thickness and is of a soft nature. It is directly overlain by the coarse pebbly Rough Rock, and it is remarkable that a current sufficiently swift to carry these materials failed to remove the soft material of which the coal was formed; possibly it was then in a wet, leathery condition. This coal is also seen near Hazlehead.

Eastward from Hade Edge the true Rough Rock has been worked on an extensive scale for building stone. Large quarries have been opened near Hazlehead and Langsett; a certain amount of the stone is used in the manufacture of silica bricks.

From Upper Midhope to Whitwell Moor the Rough Rock forms a well-marked escarpment, the dip-slope behind it falling to the north-east at angles of 6 to 7 degrees. It is about 50 ft. thick, and on the whole consists of coarse pebbly grit. In places the grit forms steep crags along the escarpment as at Wind Hill Wood and on the east side of the fault south-east of that wood.

In some localities the lowest few feet of the Rough Rock is a rather shaly sandstone, and the junction with the underlying shales is then not everywhere clearly defined. The top of the Rough Rock is exposed in the bed of the Little Don north and north-west of Midhopestones. Current-bedded grit with rootlets at the top is succeeded by the fireclay of the Pot Clay Coal.

Along the west edge of the area the Rough Rock is seen near Delph and Greenfield, Mossley, Stalybridge, and Broadbottom.

1. Delph and Greenfield.—Around Thurston Clough the upper part of the Rough Rock consists of coarse grit and contains a coal, the Sand Rock Mine, about 15 ft. below the top of the grit. No good sections of the coal have been seen here, although attempts have been made to work it; a mile west of Delph it is 15 in. thick, but of poor quality. In the lower part of the Rough Rock the grit is interbedded with much flaggy sandstone, but typical Rough Rock Flags are not developed. Flagstone is seen in the lane along the top of the steep bank west of Delph.

North of Grasscroft 35 ft. of massive grit with large concretions is exposed in old quarries. Flags are less noticeable in the lower beds here; westwards they begin to come in, an old quarry 700 yards north-west of Grasscroft showing 36 ft. of micaceous rather coarse wavy-bedded sandstone with partings of shaly sandstone. These are the lowest beds of the Rough Rock. The Sand Rock Mine with its fireclay is seen near here, resting on massive grit.

2. Mossley.—South-west of the town the lower beds of the Rough Rock just come into the area described. They form a well-marked escarpment. The Rough Rock Flags can be distinguished in this area and are shown on the six-inch maps.

3. Stalybridge.—The Rough Rock comes just within the area of the Glossop map, on the south-east side of the town (east of Hough Hill). The Rough Rock Flags are well developed and appear to be thicker than the Rough Rock itself, which is represented by only a few feet of sandstone. The upper part of the Rough Rock, showing this local weakening, is well exposed in Stalybridge, beyond our boundary.[1]

4. Broadbottom.—From the Print Works Fault south-westwards the River Etherow cuts into the Rough Rock forming a gorge from 20 to 25 feet deep; the sides are vertical to the top of the Rough Rock. Where the river turns sharply to the south-east and flows under the railway at Broadbottom the Viaduct Fault crosses from a north-north-easterly direction and throws the Rough Rock up on the south-west side. A quarry at the bend on the upthrow side of the fault shows about 40 ft. of grit, while on the same bank close

[1] 'Geology of Manchester' (*Mem. Geol. Surv.*), 1931, pp. 63-64 and 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 60, 61.

to the viaduct the grit of the Rough Rock is exposed in a cliff overlying 20 ft. of flaggy sandstone with many shale partings grading down into shale and mudstone. The throw of the Viaduct Fault is about 100 ft. This outcrop of the Rough Rock occupies a small triangular area extending westward along the railway from the Viaduct for a quarter of a mile; it is then faulted down by a north-west and south-east fault.

The complementary outcrop on the north-west side of the syncline occupies a narrow belt running north-east and south-west through Hillend, from the Viaduct fault in the north-east to the Hattersley Fault, which has a north-west and south-east trend, to the south-west. An old quarry, 200 yards south-west of Hillend, shows 30 ft. of massive coarse grit, partly shattered. The Rough Rock outcrop through Hillend forms two parallel features; the upper part of grit is separated from the lower flaggy part by a thin bed of shale. The grit is separated from the lower flaggy part by a thin bed of shale. The flaggy part is exposed in the small stream 250 yards west of Hillend, where sandstone with shale partings dips at 15° a little to the east of south.

On the south-west side of the Hattersley Fault the Rough Rock is exposed where the Hurstclough Brook cuts through its outcrop a few yards south of the point at which the fault itself crosses the brook. There the grit is dipping slightly to the east of south and is overlain by the seat-earth and coal of the Six-Inch Mine. Thence the Rough Rock outcrop extends westward to the main Tame Fault; a small branch fault throwing down west cuts the outcrop just before the railway is reached. Farther to the east the Rough Rock outcrop is represented by a belt 500 to 600 yards wide running southwards from the Mottram Fault at Woolley Bridge; it is mainly drift-covered but was proved at a depth of 22 feet in an excavation for foundations at the sewage works, 470 yards west-south-west of Melandra Castle.

CHAPTER III

LOWER COAL MEASURES

Introductory

The Lower Coal Measures occupy about one quarter of the area shown on the map; of this only some 4 to 5 square miles in the north-east corner is overlain by Middle Coal Measures, leaving roughly 50 square miles of outcrop.

Though the palaeontology and the presence of the Upper Meltham Coal (pp. 20, 21) suggest that the base of the division would have been better taken at the top of the White Rock, the line has always been drawn at the top of the Rough Rock. The presence of a marine band a few feet above the latter throughout Lancashire, Yorkshire and part of Derbyshire shows that the horizon chosen for the boundary is consistent for at any rate the East and West Pennine coalfields, and there is, therefore, no good reason for suggesting any change.

The division between the Lower and Middle Coal Measures is taken at the coal seam known as the Silkstone or Blocking Bed. This is a purely conventional boundary-line. The palaeontological and palaeobotanical break occurs, however, at the top of the Elland Flags or Greenmoor Rock; this corresponds with the horizon of the Arley Mine Coal in Lancashire, the level adopted as the top of the Lower Coal Measures in that coalfield.[1] In some parts of the Eastern Pennine Coalfield this line is difficult to trace. On the other hand the Silkstone or Blocking Coal can be fairly readily traced throughout the coalfield.

The thickness of the division, thus defined, is nowhere given by borings or shaft sections, and can only be calculated from the outcrops. In the area to the north it has been given as 1,500 ft.[2] Along the line of section engraved on the map it is less than 1,150 ft. In the south, outcrops of the Silkstone Coal, a short distance beyond our boundary, south-east of Penistone, combined with a deep boring, make the total about 1,670 ft. The apparent thinning in the intermediate area could be explained in two ways. If the beds are thickening eastwards the figure calculated from the outcrops of the Rough Rock in the west and the Silkstone Coal in the east would be too small: such a thickening would indicate that an uplift was already taking place in Lower Coal Measure times along the Pennine Axis. If, however, there is an actual thinning along the strike from both directions to the position of

[1] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 275-285; and D. A. Wray and A. E. Trueman in 'Summary of Progress' for 1930, Part iii (*Mem. Geol. Surv.*), 1931, pp. 71-76.

[2] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 49.

the line of section an uplift along an axis running about east-north-east would be indicated. Such an axis has already been postulated by Dr. Wray mainly to account for variations in the Barnsley Coal.[1] As disturbances are also found in the Silkstone and the Whinmoor coals (pp. 99, 111) its existence throughout Coal Measure times is not an unreasonable supposition; moreover there are some reasons for thinking that it may have been in operation during the formation of the Millstone Grits (see below, p. 127).

The most conspicuous feature of the Lower Coal Measures is the escarpment capped by the Greenmoor Rock and Grenoside Sandstone (Plate IVA). The former lies some 600 ft. above the Rough Rock in the extreme north, drops to 400 ft. near Jackson Bridge, and thence to the south-east gradually increases again to about 650 ft., figures which well bring out the thinning along the axis mentioned above, since the outcrop is comparatively narrow, often less than half a mile. This prominent feature crosses the area diagonally from the eastern bank of the Holme valley near Honley in the north to the northern bank of the Little Don near Midhopestones, but is broken up by faulting near Hepshaw, where the distance from the Rough Rock outcrop to that of the Greenmoor Rock is nearly two miles.

The Greenmoor Rock is the local representative of the Elland Flags to the north and the Wingfield Flags of Derbyshire, both of which have a considerably greater thickness. The escarpment is a continuation of that which passes through Halifax and Elland Edge.[2] Other important sandstones in the Lower Coal Measures are the Grenoside Sandstone and the Penistone Flags. Though these and lesser bands of rock may form striking features locally, they are "more finely grained and thinner than the Millstone Grit beds, more apt to change their lithological character and sometimes die away altogether."[3] The scenery is tamer than that of the Grits, though patches of open moor occur on the Greenmoor Rock, Grenoside Sandstone and the Penistone Flags.

Economically the measures are not of great importance. In the lower part the Soft Bed and Hard Bed coals have been worked to a small extent for local consumption. The Greenmoor Rock is a valuable building stone quarried around Shepley and elsewhere. In the Cumberworth and Denby Dale districts the Cumberworth Thin Coal is underlain by an important fireclay which is being actively exploited; the Whinmoor Coal, lying a short distance above, is worked in conjunction with the clay.

General Stratigraphy

Measures below the Hard Bed Coal.—Immediately on the Rough Rock lies a fireclay with a thin but persistent seam of coal known as the Pot Clay Coal, a name introduced in the Sheffield

[1] Wray, D. A., 'The Barnsley Coal and its Variations,' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 137.
[2] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 53.
[3] 'Geology of Part of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1869, p. 4.

district where the fireclay has been worked for pot-making. To the north it has received the unsatisfactory name of the 'Thin Coal,' applied in this district to a seam higher in the sequence. The coal is seldom more than a few inches thick, the fireclay usually about 4 ft.

The shales forming the roof of the coal contain marine fossils, including *Gastrioceras subcrenatum* (Schloth.), *G. listeri* (Mart.), *Posidoniella multirugata* J. W. Jackson, *Pterinopecten papyraceus* (J. Sow.) and fish-remains (p. 156); they are referred to as the Subcrenatum band.

The next coal is known as the Soft Bed: in the north it is 80 to 100 ft. above the Pot Clay Coal; near Brockholes the intervening measures consist entirely of shale. Around Huddersfield the coal is immediately underlain by the Soft Bed Flags, which may be as much as 150 ft. thick[1]; but they die out rapidly to the south, being represented near Honley Station by a series of thinly laminated flagstones separated by thick shale partings. In the central area near Tinker Hill these beds are about 100 ft. thick and include a sandstone separated from the Soft Bed by about 30 ft. of shale; towards Hazlehead the coal rests directly on this sandstone, which may be compared with the Soft Bed Flags of Huddersfield or the Crawshaw Sandstone to the south,[2] but near Langsett the rock again dies out, and in the extreme south-east some 130 ft. of shale separates the Pot Clay and the Soft Bed coals. The latter has been worked to a considerable extent, and has valuable properties. It has a very low sulphur content and a good coking index (p. 172). Its thickness varies considerably: in the north it is 20 to 24 in.; near New Mill 20 in.; from Hepworth to Carlcotes it drops gradually to as little as 3 in., but increases again to 24 in. west of Langsett and 36 in. near Midhopestones; farther east it again decreases.

From the Soft Bed to the Hard Bed is about 90 ft. in the north, 60 ft. at Thongsbridge and New Mill, 75 ft. at Hepworth, 150 to 160 ft. at Hazlehead and Langsett and 200 ft. at Midhopestones. The measures are mostly sandy shale. A short distance above the Soft Bed is a *Carbonicola* band which has been found at a number of points (p. 163). About midway between the Soft Bed and the Hard Bed is a thin coal known as the Middle Band or Clay Coal, to be distinguished from the Pot Clay Coal at the base of the division. It is only a few inches thick, 9 in. being the maximum recorded; it usually rests on a band of sandstone which thins out locally near Hepworth. Near the 'Moor Cock,' the inn marked on the map one and a quarter miles south of Hepworth, a ganister comes in as the seat of this coal; it is largely worked for the manufacture of silica bricks, but has not been used farther east than Bullhouse Wood east of Hazlehead Station.

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 49.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 93.

The Hard Bed Coal.—The Hard Bed is one of the principal seams of this area, and has been largely mined in the past; the ganister and fireclay beneath it add to its importance. In the north the section is:—coal 2 ft. 3 in., ganister varying round about 3 ft. and fireclay 2 ft. Between New Mill and Hepworth the coal decreases to 1 ft. 6 in. From Hepworth to Hazlehead the coal sometimes reaches 2 ft. 6 in. and has mostly been worked; near Midhopestones it is about 3 ft. thick with about a foot of ganister below. The coal is pyritous and has a high sulphur content; it is not so much used now as formerly, though it is still mined to some extent as a household and steam coal, mainly for local purposes.

The roof of the Hard Bed Coal is a marine bed characterized by *Gastrioceras listeri* and allied forms, together with *Posidoniella multirugata* J. W. Jackson, *Posidonomya gibsoni* Salter, *Pterinopecten papyraceus* (J. Sow.), etc. These fossils occur both in the roof-shales and in calcareous or pyritous nodules in the shale; in the latter case goniatities are uncrushed. Coal-balls, that is similar nodules in the coal containing petrified plant-remains, are well known at this horizon in the Halifax district,[1] but are not known to occur in this area.

From the Hard Bed Coal to the Greenmoor Rock or Elland Flags.—These measures are about 350 ft. thick near Honley, 460 ft. west of Thurstonland, 380 ft. between New Mill and Hepworth, 350 ft. at Crow Edge and the Hepworth Iron Works, 480 ft. near Hazlehead and 420 ft. in the extreme south-east. They are noticeable for the presence of two coals, the Hard Bed Band, Lower Band, or 40 Yards Coal and the Upper Band or 80 Yards Coal. The last names indicate the approximate distance above the Hard Bed Coal; they correspond with the 36 Yards and 80 Yards Band Coals of the country to the north.[2] The 40 Yards Coal is usually underlain by a thin rock band and a fireclay which has been worked near Bullhouse Colliery, but is only 6 in. to 1 ft. thick; the clay is up to 3 ft. (p. 175). The shales above contain numerous ironstone nodules which were formerly worked at Crow Edge, mainly from just above the coal.

The 80 Yards or Upper Band Coal can be traced through the greater part of the area by the presence of a sandstone, the 80 Yards or Upper Band Rock, immediately beneath it, though north of Brockholes it is very irregular and may sometimes be absent; elsewhere the rock varies from 10 to 30 ft. The coal varies from a mere smut up to 1 ft., and the fireclay beneath is sometimes as much as 4 ft. thick. The blue shales above it are worked for drain-pipes, etc., near Crow Edge.

The Elland Flags or Greenmoor Rock.—On the Old Series one-inch map of this area, Sheet 88 S.E., the name Greenmoor Rock is used exclusively for this sandstone, but the name Elland

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, pp. 51, 52, 165, 166.
[2] *Ibid.*, p. 52.

Flags is in common use for stratigraphical purposes throughout the Yorkshire Coalfield. The former name is better applied to a homogeneous non-fissile sandstone which, in the present area, constitutes in some parts the whole and in others a considerable proportion of the series known as the Elland Flags. "The Greenmoor Rock is, perhaps, the most beautiful and valuable stone of the Yorkshire Coal Measures. The best parts of it are very finely, evenly, and closely grained, and of a pale blue colour, thickly bedded, and with no tendency to split into flags . . . This blocky stone seems to be made up of a large number of very thin laminae of grains of sand, but the deposition must have gone on steadily and without interruption, so that no one layer had time to harden before the next was laid down upon it, and no planes of division were established between the layers. We very frequently can observe the same minute division into layers of sand in the Flagstone, but in the inferior kinds the layers do not adhere so closely together, and the stone, when exposed to the weather, scales off in thin flakes."[1] Greenmoor, from which the name is taken, lies one and a half miles east of our boundary between the valleys of the Don and the Little Don.

In the north, between Farnley Tyas and Thurstonland, there are two beds of flags separated from one another by 50 to 120 ft. of shale, the whole series being about 330 ft. thick. East of Jackson Bridge and Hepworth there are two beds separated by a varying thickness of shale, but both of a non-flaggy sandstone referred to as Greenmoor Rock; they crown the fine escarpment, forming prominent plateaux due east of each village, the outcrop between, below Pike Lowe, being narrow. The northern plateau is prolonged to the east-north-east to Lane Head and the Sovereign Inn, where the rock forms a continuous bed and is quarried on a large scale (p. 90); the outcrop is then cut off by the Cumberworth Fault. The southern of the two plateaux is occupied by moorland known as Cheese Gate Nab; thence the scarp continues to the Don valley which is crossed at Thurlstone, the rock again splitting into two bands. At Hartcliff Hill the Greenmoor Rock forms a prominent feature, but the Tower marked on the map is on the higher Grenoside Sandstone a quarter of a mile east of the scarp; the rock is a single bed, 40 ft. thick, and has been much quarried between here and Thurlstone, but there are three thin bands of sandstone between it and the Upper Band Coal 160 ft. below, which represent the Elland Flags. At Penistone a borehole gives the following section[2]:—

		Ft.	In.
Flagstone 54 ft. 4½ in.	Bind (shale)	21	0
	Hard stone	16	6½
	Blue bind and ironstone	14	8½
	Hard stone	11	10½
	Gritstone	9	10
	Hard stone	1	5

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 125.
[2] *Ibid.*, p. 126.

The site of this bore is on Penistone Common, near Cliff House on the west side of the road to Midhopestones.

The Better Bed and Black Bed Coals.—The Better Bed Coal has been of great importance in the country to the north on account of its freedom from objectionable impurities, but is now nearly exhausted; in fact, the many pits belonging to the Low Moor Iron Company mentioned as working it in the memoir on that district have now closed down.[1] Its presence in the north and absence in the south is, economically, one of the important differences between the West Yorkshire and the South Yorkshire districts of the coalfield.

Within the area of the Glossop Sheet it is present only near Kirkburton, to the west of which the outcrop has been worked, the section being: coal, 1 ft. 6 in.; fireclay, 4 ft. 6 in. Elsewhere it is absent or represented by a mere smut, though the fireclay is traceable for a considerable distance farther, and has been found here and there throughout the area, just above the Elland Flags or Greenmoor Rock; Green has recorded its presence at Shepley, High Flats, Thurlstone, and near Midhopestones.[2] What is believed to be the Better Bed Coal has been proved in deep borings for water at Skelmanthorpe, over two miles east of the outcrop (see p. 183). Although no satisfactory core was obtained, the coal was estimated to be over three feet thick at this point.

The Black Bed Coal, of great economic importance in the West Yorkshire Coalfield, is similar in its distribution to the Better Bed; within our area it is present only in the neighbourhood of Kirkburton, where it is also known as the Tinker Coal; it lies about 120 ft. above the Better Bed, the intervening measures being shale and mudstone with thin lenticles of flaggy sandstone. It has been worked from the outcrop and also mined from Box Ings Colliery under Shelley Wood, between Shelley and Kirkburton; the section there is: engine coal 9 in., dirt 3 in., stone or gas coal 9 in.[3] This seam should be distinguished from the Black Band Coal higher in the sequence (p. 83, 84).

The Grenoside Sandstone.—About 100 ft. above the Greenmoor Rock is the Grenoside Sandstone; where the Black Bed Coal is present the sandstone is immediately above it. The rock is usually a thickly bedded, rough, gritty sandstone, contrasting in this respect with the evenly and finely grained flagstones below. It is 30 to 50 ft. thick in the north, increasing southwards to 75 and 100 ft. and is almost free from shale partings. It forms a more conspicuous feature, and has a more extensive outcrop than any other Coal Measure sandstone within our boundaries. In the north, Farnley Tyas, Kirkburton, Thurstonland and Shepley are situated on it; from Pike Lowe its dip-slope extends to the Cumberworth Fault, a maximum distance of three miles,

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, pp. 54, 55, 74, 75, 176.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 128, 129.
[3] *Ibid.*, p. 136.

and along the strike to Thurlstone and Langsett Common averages over half a mile in width.

A thin coal present throughout the area just above this rock is known as the Grenoside Sandstone Coal; it is probably the equivalent of the Crow Coal of the country to the north.[1] It is usually only a few inches thick, though it has been worked from day-eyes beside the main road south-east of Cumberworth Church. Between Shelley and Shepley it rests on a fireclay 4 ft. thick.

The Penistone Flags.—From 50 to 100 ft. above the Grenoside Sandstone a variable series of flaggy beds sets in, known as the Penistone Flags. At the type-locality a generalized section is as follows[2]:—

		Ft.	In.
	Cumberworth Thin Coal	—	—
	Shale	25	0
Penistone Flags 167 ft.	Charlton Brook Coal	0	9
	Sandstone (C)	30	0
	Shale	30	0
	Penistone Green Coal	0	9
	Sandstone (B)	20	0
	Shale	25	0
	Lower Penistone Coal	0	6
	Sandstone (A)	60	0
	Shale with a thin coal in the middle	90	0
	Grenoside Sandstone	90	0

From the above it will be seen that each of the three sandstones is overlain by a coal, of which the Lower Penistone Coal is the most persistent; none of them is of appreciable economic value.

South-eastwards from Penistone the general character of this group shows little change, but to the north-west, while individual beds can seldom be identified with certainty, it seems probable that sandstones A and B die out in a few miles. Around High Flats the Grenoside Sandstone is separated from the Cumberworth Thin Coal by only about 100 ft. of measures, the section being shale 40 ft., with a thin coal (? Lower Penistone) near the top, sandstone 40 ft., shale 20 ft. Farther north, however, the group again increases in importance, three sandstone beds being present. Around Scissett an average section is:—

		Ft.	In.
	Cumberworth Thin Coal	—	—
	Fireclay	3	6
	Flagstone	25	0
Penistone Flags 156 ft. 10 in.	Sandy shale	65	0
	Flagstone	15	0
	Coal (? Lower Penistone)	0	10
	Shale with flaggy stone bands	42	0
	Delf flagstone	9	0
	Shale	76	0
	Grenoside Rock	—	—

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, pp. 59, 77, 78.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 137.

The town of Skelmanthorpe is built on the outcrop of these beds, mainly that of the middle sandstone. To the north-west, around Kirkburton and Shelley the sandstones practically die out, 200 ft. of shale with two thin coal seams and sometimes a little sandstone at the top separating the Grenoside Sandstone from the Whinmoor Coal.

The Whinmoor Group of Coals.—Over the greater part of the area a group of three coals can be recognized, termed in ascending order, the (Cumberworth) Thin, the Whinmoor and the Black Band coals. They correspond roughly with the Beeston Group of the West Yorkshire district of the coalfield, to which the part of our area north of the line of section belongs. Consequently a variety of names is in use. The ' Thin Coal ' is the accepted name for a seam which is of considerable importance in the neighbourhood of Cumberworth and Denby Dale on account of its valuable fireclay. As the name has, not unnaturally, been used in other parts of the field for seams at several different horizons, we distinguish it by calling it the Cumberworth Thin. In the north it is sometimes referred to as the Low Whinmoor, sometimes as the Low Lousey. The name ' Lousey ' has little or no stratigraphical significance, as it is applied to any low grade or relatively worthless seam of coal regardless of the stratigraphical horizon. The ' Top Lousey ' is another unimportant seam in the measures above the Whinmoor group.[1] The Cumberworth Thin Coal is seldom more than 1 ft. 3 in. thick, but the fireclay is usually about 4 ft., sometimes with a little ganister. The beds between this seam and the (Top) Whinmoor Coal are usually 40 to 60 ft. in thickness, but of variable nature; they may be entirely shale or entirely sandstone within a distance of less than a mile.

The Whinmoor (or Top Whinmoor) Coal is now the most important seam in the district; it has been or is being worked wherever present at shallow depth, though it has hardly been touched where Middle Coal Measures are present above it. It is usually in three bands separated by dirt partings, a typical section at Cumberworth being: coal, 1 ft.; dirt, 1 ft.; coal, 1 ft. 5 in.; dirt, 10 in.; coal, 1 ft. 8 in. The workings are mostly by adit in connexion with those for the Cumberworth Thin fireclay; but some coal is sold for general purposes.

The measures between the Whinmoor and the Black Band coals are again variable; the thickness may be from 10 to 50 ft. and the material all sandstone, all shale or a mixture; more usually the roof is a sandstone.

The Black Band Coal is sometimes referred to, in the north, as the Shertcliffe and more rarely as the Beeston. It varies from 1 ft. or less up to 2 ft. 8 in. in thickness. It has been worked

[1] The various names in use for the seams constituting this group in the country of the north and the manner in which certain of the seams coalesce to form the Beeston Seam is fully discussed in the memoir on that district, ' Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, Chap. III.

from outcrop, and between Shelley and Royd House was mined at a depth of 84 ft., the thickness being 18 in.; at Cumberworth Colliery it is 2 ft. 1 in. On Quarry Hill between Denby Dale and Nether End it lies immediately beneath a sandstone which caps the hill, but is nowhere exposed and appears to be thin; farther south only lower measures are present.

The following sections give a general idea of these measures and their variability:—

	Ft.	In.
East of Kirkburton.		
Shale	—	—
Black Band or Shertcliffe Coal ... 1 ft. 6 in. to	2	0
Shale with impersistent sandstone	30	0
(Top) Whinmoor Coal with dirt parting 1 ft. thick ...	2	8
Shale, sometimes with a thin sandstone	24	0
Low Whinmoor (Cumberworth Thin) Coal, drubby...	1	2
Wood Nook, three-quarters of a mile south-east of Shepley Station.		
Shale	—	—
Black Band or Shertcliffe Coal	2	0
Shale	27	8
Whinmoor Coal with two dirt partings 1 ft. 10 in. ...	6	4
Shale ... ... about	25	0
Cumberworth Thin Coal (on fireclay 4 ft. 6 in.) ...	0	10
Denby Dale, south side of valley.		
Sandstone	—	—
Black Band Coal	?	
Shale	60	0
Sandstone	25	0
Whinmoor Coal, with two dirt partings 1 ft. 4 in. ...	4	10
Shale	25	0
Cumberworth Thin Coal (on ganister 2 ft. 6 in., clay 4 ft.)	1	3

Near Nether End both the Cumberworth Thin and the Whinmoor coals appear to be washed out.

From the Black Band to the Blocking or Silkstone Coals.—These measures amount to about 175 ft. east of Kirkburton and Shelley, where they consist of shale with several thin sandstones and some impersistent coals of little value. Near Denby Dale and Clayton West the thickness is much reduced, sometimes appearing to be as little as 30 ft., consisting almost entirely of sandstone. There is evidently a line of contemporary disturbance in this region which renders exact correlation uncertain. In the north the most important of the coals is known locally as the Lousey or Top Lousey Coal; it appears to correspond with the Lousey Coal of the Whitley and Lepton district,[1] but is nowhere workable.

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 62.

In Bagden Park what is probably the same seam lies 80 ft. above the Whinmoor; in Deffer Wood south of Wheatley Hill traces of two or more coals have been found, but the outcrops could not be followed. A boring at Park Mill Collieries (on the edge of the map, and north of the railway at Clayton West) proved the measures between the Silkstone (or Blocking) Coal and the Top Beeston or Shertcliffe Seam to be 100 feet thick. Eight feet above the latter seam occurs a thin unimportant seam locally known at the ' Little ' Coal. This seam can generally be recognized in the district between Thornhill, Lepton and Clayton West. In the measures between the Silkstone and Little coals, three seams of ' Lousey ' Coals occur at Park Mill (see p. 101).

Details

Measures below the Hard Bed Coal.—A section of the Pot Clay Coal and the overlying marine band was seen during the recent re-survey in an old quarry at Steps alongside the railway, 500 yards north of Honley Station. The whole section was obscured by debris and the coal and fireclay imperfectly exposed. The shales, however, were very fossiliferous and yielded abundant impressions of *Gastrioceras subcrenatum* (Schlotheim) and *Pterinopecten papyraceus* (J. Sow.).

Around Brockholes this thin band of coal and underlying fireclay can be traced above the Rough Rock, an excellent section of these beds being exposed in the Holmfirth branch railway-cutting, 600 yards south of Brockholes Station. The full section here is as follows:—

Section in Scar End railway-cutting, Brockholes.

	Ft.	In.
9. Dark shaly mudstones	8	0+
8. Soft black shale with abundant impressions of *Pterinopecten* and *Gastrioceras sp.* Sandy lenticular nodular bands occur with imperfect casts of fossils	0	9
7. Dark shaly mudstone	1	6
6. Pot Clay Coal	1 to 0	2
5. Hard ganisteroid sandstone, very variable ...	0	9
4. Soft yellow fireclay	1	6
3. Hardened nodular micaceous impure fireclay ...	2	6
2. Sandy micaceous shale with occasional rootlets ...	7	0
1. Rough Rock. Massive-bedded gritstone ...	15	0+

The coal and fireclay are also imperfectly exposed at several points in the New Mill Dike valley between Mytholm Bridge and New Mill. In Sinking Wood Nook, 1,000 yards east of Thongsbridge railway station, the coal, about 3 in. thick, rests on a thick bed of fireclay. The marine roof can also be recognized here.

This horizon is exposed near Hepworth in the banks of the brook that rises at Ox Lee: about 18 in. of fireclay rests on the top of the Rough Rock, the coal is 2 in. thick; the shale with marine fossils overlies it and passes up into shale with plant-remains and ironstone nodules.

These beds are also seen at old workings in a small stream one third of a mile west-south-west of Tinker Hill. At the entrance to a day-hole near Softley (Soughley) the section is as follows:—

	Ft.	In.
Shale	0	6
Marine bed	0	8
Black shale	1	6
Coal	0	2
Fireclay	—	—

The fireclay is of a sandy nature and has certain characteristics which tend to suggest that its original deposition as a shale was succeeded by a longer land period than the 2 in. of overlying coal would lead one to suppose. The bed is well exposed in the Little Don about half a mile below Langsett where the marine bed is rich in fossils. Between 800 and 900 yards north-west of Midhopestones Church the section is:—

	Ft.	In.
Hard black shale ... ... seen	4	0
Soft black shale with *Pterinopecten sp.* and *Gastrioceras* in upper part	2	6
Hard splintery black shale. (Burns with a bright flame)	0	6
Hard coal	0	8
Seat-earth	1	2
Shaly coal	0	4
Seat-earth, hard in lowest foot	2	6
Flaggy sandstone with rootlets, passing down into grit	—	—

Other sections which differ slightly from this one have been noted near by.[1]

The Soft Bed Coal has been worked at many points along the outcrop and occasionally mined at shallow depths. North-east of Honley it was of fair quality and varied from 1 ft. 8 in. to 2 ft. in thickness. At Sally Wood Mine on the east side of New Mill, which was being worked from day-eyes at the time of the re-survey, it was 18 to 20 in. From here to Hepworth there are many disused shafts between the outcrop of the coal and the scarp of the Greenmoor Rock, varying in depth up to 97 yards.

West of Hepworth the thickness of this bed is only about 3 or 4 in. at Tinker Hill, but was rather thicker, 10 in., near the Moor Cock Inn where it was formerly worked on a small scale. Between Carlecotes and Crow Edge it has been worked by the Hepworth Iron Co.; the section was coal 6 in., fireclay 2 ft., with a sandstone floor and shale roof. Southward from Hepworth the coal remains thin and is about 10 in. near Hazlehead Hall, where it rests directly on a thin sandstone. Southwards from there it rapidly thickens and is 1 ft. 3 in. near Ranah and 3 ft. at Hard Bank, one mile south-east of Langsett, where it has been worked on a considerable scale; there are no signs of a sandstone below it here.

The Soft Bed Coal crops out in the north bank of the reservoir below Sheephouse Wood; the section 530 yards east-north-east of Midhopestones Church is:—

	Ft.
Black shale with fish scales	4+
Coal	3
Seat-earth	2+

A further 200 yards to the east the thickness appears to be only 23 in., with a shaly parting near the top; the section is, however, not reliable, owing to surface-creep.

The thickness must decrease again to the east, for at Stocksbridge it is little over a foot.

The shales which crop out in the faulted area between the Little Don and the Rough Rock of Whitwell Moor, and which contain a *Carbonicola* band (badly exposed 130 yards north-north-east of the farm called Green), are probably just below the Soft Bed.

A short distance above the Soft Bed Coal is a *Carbonicola* band which appears to be persistent throughout the area (p. 163); it is well exposed in the sides of the private railway to Hazlehead Colliery, where Entomostraca and fish scales are abundant; an exposure in a small valley north of the high-road just over half a mile north-west of Midhopestones shows *Carbonicola*

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 88, 89.

spp. in two bands about 20 ft. apart. The measures above usually contain a sandstone succeeded by the Middle Band Coal.

The Middle Band Coal, often only a few inches thick, is persistent throughout the area; near New Mill and Hepworth it has been called the Clay Coal; it lies 40 to 45 ft. above the Soft Bed.

An excellent section of the measures above and below the Middle Band and Soft Bed coals is exposed in the railway-cutting 100 yards north of Honley Station. Here the thin band of black shale immediately overlying the Middle Band Coal yields *Lingula* and abundant fish scales. The full section is as follows:—

	Ft.	In.
Dark shaly mudstones with bands of ironstone nodules	20	0
Fine black shales with *Lingula* and fish scales ...	0	9
Middle Band Coal	0	10
Hard ganister rock with rootlets	0	9
Fireclay with rock bands	3	0
Hard flaggy sandstone...	1	6
Black shales and shaly mudstones	30	0
Shale crowded with *Carbonicola* impressions... ...	0	6
Black shale	12	0
Soft Bed Coal	1	9
Fireclay; upper part flaggy and ganisteroid with rootlets	5	0
Shaly mudstone with flaggy layers	6	0
Hard flags, rather massive	6	0+

From Honley the Middle Band Coal can be traced to Brockholes, and alongside the railway 200 yards north of Brockholes Station it is well exposed in a deep cutting. It here overlies a band of hard ganister rock about 6 ft. thick. In the railway-cutting at the western end of Thurstonland Tunnel it is also exposed and here the underlying band of hard ganisteroid sandstone attains a thickness of some 12 ft. The underlying sandstone thins away to the south and is unrepresented along the eastern slopes of the Holme valley to the north of New Mill. Ganister is again seen near Millshaw Grove, three-quarters of a mile south-east of Hepworth Church. Farther south the ganister has been extensively worked for the manufacture of silica bricks; at Little Law, 300 yards south of the Moor Cock Inn, Hepshaw, it lies about 3 ft. below the surface and has been stripped over a large area. The bed is also seen in the Hepworth Iron Co.'s workings near Crow Edge, where the overlying coal is 9 in. thick. Old workings in the ganister occur in Bullhouse Wood, east of Hazlehead Station.

The Hard Bed Coal.—The important seam known as the (Halifax) Hard Bed or Ganister Coal has been extensively worked; the presence of ganister below it adds to its economic value, and this and the marine roof make its identification throughout the coalfield certain. The coal has been worked along the outcrop to the north and east of Honley Station and its outcrop can be very readily recognized by the presence of marine fossils in the shale tips.

The ganister underlying the coal is at present being worked in a quarry 400 yards east of Honley Station. The Hard Bed Coal is here 2 ft. 3 in. thick and its upper surface is strongly pot-holed, the hollows being filled with fine black silty shale. The underlying ganister rock, which is quarried for the manufacture of silica bricks, averages about 2 ft. in thickness, occasionally attaining a thickness of 3 ft. (p. 174). The underlying fireclay was formerly worked and sent away to the Potteries but was stated to be not pure enough to repay working. The Hard Bed Coal also crops out in the railway-cutting 800 yards north of Brockholes railway station. There are several old outcrop workings along the eastern side of the railway. In the large section exposed at the western end of Thurstonland Tunnel the Hard

Bed Coal with an easterly dip is well seen resting on about 3 ft. of hard ganister rock. From this district the outcrop can readily be followed southwards by a succession of old crop-workings along the eastern slopes of the New Mill valley. Around Thurstonland the Hard Bed Coal has been mined somewhat in the past, but all these workings are now standing.

At the Hollow Gate Shaft, 400 yards south-west of Thurstonland Church, the Hard Bed Coal was met with at a depth of 100 yards. The coal here was 1 ft. 11 in. thick and rested on 1 ft. 2 in. of ganister rock above 3 ft. 2 in. of fireclay.

Four hundred yards west of Hollow Gate Shaft there are old shallow workings in the coal and a full section of the shaft at this point was as follows:—

	Ft.	In.
Clay	4	0
Shale	10	6
Rock	3	0
Clod	0	6
Coal	1	9
Ganister...	1	2
Fireclay...	3	2

From New Mill to Hepworth the coal has been got from a number of shafts and day-eyes on the east side of the valley; there is here much pyrites in the roof and some in the coal itself; the section at a day-eye and opencast working at Coal Pit Wood about half a mile east-south-east of Jackson Bridge was:—

	Ft.	In.
Shale	—	—
Coal smut	0	2
Shale	10	0
Marine band with fossils and pyrites	3	0
Hard Bed Coal	1	0
Ganister...	—	—

Between Hepworth and the Great Central Railway the coal is now mostly worked out over a large area which extends eastwards from the crop to the present limit of the workings of Crow Edge, Hazlehead and Sledbrooke collieries: the seam is 2 ft. 6 in. to 3 ft. thick and contains many pyritous nodules, which were formerly used for the manufacture of copperas (iron sulphate). At Hepworth Iron Works a section in open workings in 1913 was coal 2 ft. 3 in., ganister 9 in., fireclay 5 ft. 9 in., with a floor of inferior fireclay and a shale roof. It is also worked at Bullhouse Colliery and at Aldermans Wood near Langsett; at the former the coal, 3 ft. thick, is reached at a depth of 318 ft.; two parallel faults encountered in the workings here were found to be infilled with vein-stuff consisting of comby pyrites and calc-spar.[1] Near Midhopestones there are many old workings along the side of the hill in Sheephouse Wood; the coal is 3 ft. thick and the ganister 1 ft.

From the Hard Bed Coal to the Greenmoor Rock or Elland Flags.—Above the marine band which overlies the Hard Bed Coal is a series of dark shales, usually about 100 ft. thick, succeeded by a thin band of hard sandstone, on which rests a thick bed of fireclay and a thin coal known as the Hard Bed Band or Lower Band Coal. The shale is worked near Crow Edge for tile-making, and near Bullhouse Colliery the sandstone is used as a source of silica for silica bricks. The coal there is thicker than in the north. The shaft section at the colliery is as follows[2]:—

[1] 'Geology of Part of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1869, p. 13.
[2] 'Sections of Strata of the Coal Measures of Yorkshire,' *Mid. Inst. Mining Eng.*, 2nd edition, 1927, p. 74.

	Ft.	In.
Shale	172	6
Hard Bed Band Coal { Coal	1	8
Hard Bed Band Coal { Fireclay	2	0
Hard Bed Band Coal { Coal	0	9
Fireclay	2	6
Rock with thin shale bands	12	0
Dark fireclay	1	6
White soapy fireclay	2	0
Clunch	7	0
Strong bind	2	6
Black shale	90	1
Black shale with thin ironstone bands	21	0
Hard Bed Coal	3	0

To the east of Honley the Hard Bed Band or Lower Band Rock forms a prominent feature at Hollin Hall and thence it can be traced southwards along the eastern slopes of the Holme valley to the top of the railway tunnel, Thurstonland. It also forms a marked feature at Stagwood Hill and Biggin Shrogg half a mile to the south of Thurstonland village. It is here much cut up by east-and-west faults. At Fulstone the dip-slope of this rock extends south-east from the village, and in the beck to the east of the village the overlying fireclay and coal could be recognized. East of New Mill and Hepworth the Lower Band Rock cannot always be traced in the hillside, but the coal is 7 in. and the fireclay 2 ft. thick; they were formerly worked in conjunction here and in the Crow Edge district, the clay being used for pot-making.

The next coal, the Upper Band or Eighty Yards Coal, is even thinner than the Lower Band, but the sandstone beneath it is thicker and more persistent. To the north-east of Honley this rock gives rise to two prominent features, one known as Stirley Knoll, and the other an unnamed feature at the north-western corner of Hey Wood. To the north-east and east of Brockholes the 80 Yards Rock forms a prominent feature at Longley Hill, while to the west of Thurstonland it forms a distinct shelf, apparently thinning or dying out altogether to the south of that village. Between Fulstone and the Wakefield road, however, a fine grey sandstone forms a comparatively wide spread and its narrow outcrop can be followed southwards round the scarp; the overlying fireclay has been seen here and there. In the south, near Sheephouse Wood, the rock is separated by shales from the coal, and is about midway between the two Band Coals.

The beds between the Upper Band Rock and the base of the Greenmoor Rock are usually blue shales, which are worked for drain-pipes, etc., at Calf Hey Dyke, near Crow Edge. In the south-east a sandstone is present almost immediately above the Upper Band Coal, but is not traceable west of Sheephouse Wood.

The Elland Flags or Greenmoor Rock.—Between Hey Wood and Farnley Tyas the Elland Flags consists of two main beds separated by sandy shale. In an old quarry 300 yards west of Farnley Tyas Church the upper bed is exposed and shows 15 ft. of fine-grained buff or yellow flaggy sandstone. The same beds are also exposed in the steep hollow known as Range Dike to the east of Farnley Tyas. They cover a large area to the north of Thurstonland and give rise to a marked escarpment visible for many miles at Thurstonland Bank to the south-west of the village.

In a group of old quarries at Height Green, about 1,000 yards north-west of Thurstonland Church, the Greenmoor Rock consists of hard massive flaggy sandstone with many partings of sandy shale. The uppermost bed is a hard ganisteroid sandstone overlain by fireclay. No coal is present though this is apparently the stratigraphical horizon of the Better Bed Coal in the country to the north. At Thurstonland Bank the shaly mudstones which occur between the upper and lower bed of the Elland Flags have been somewhat extensively quarried for brick-making. These works are now standing. The full section exposed here is as follows:—

	Ft.
Flaggy sandstone with occasional shaly partings ...	12
Soft shales	1
Flaggy sandstone with shaly partings	2
Grey shaly mudstones	2
Prominent band of hard flaggy sandstone	2
Soft light grey sandy flaggy and shaly mudstones worked for bricks	20
Rather massive flaggy sandstone	12+
Base of quarry.	

A section of the uppermost beds of the Greenmoor Rock is seen at the eastern end of the Thurstonland railway tunnel; about 25 ft. of alternating sandy shales and flaggy sandstone is exposed; some of the higher beds of sandstone are of a ganister-like nature and contain abundant Stigmarian rootlet impressions.

The Greenmoor Rock forms prominent shelf-like features along both sides of the Thunderbridge valley and also in the tributary valleys of the Stocksmoor and Carr Dikes, the main features, however, in this area are produced by the overlying Grenoside Rock. At Thunderbridge village there are several disused quarries in the Greenmoor Rock. These all show rather massive-bedded flaggy sandstone but with numerous irregular wedges of false-bedded flaggy shale. In the Stocksmoor valley at Stocks Wood the whole series consists of a rapid alternation of flaggy sandstone and sandy shale.

Near the Sovereign Inn at Lane Head, south of Shepley, the Greenmoor Rock is largely quarried by a number of firms: a typical section is as follows:—

	Ft.
Shale	—
Rag	10
Sandstone	12
Flags	5
Shale	10
Sandstone, in places slightly flaggy	25
Shale	3
Stone	20+

The two bottom beds are referred to as the 'Bull Holes.'

To the south-west two bands can be separately mapped: the lower has a wide outcrop at the Mount, east of Jackson Bridge, but becomes thin and forms only a narrow shelf east of Hepworth, where the upper bed widens out to form Cheese Gate Nab; old quarries here show a fine-grained sandstone, flaggy in the lower part. The two beds can be followed past Whitley Common to the River Don at Thurlstone; they are separated by a bed of blue shale; the upper is the Greenmoor Rock proper, the lower a variable sequence of flaggy sandstones and sandy shales corresponding to the Elland Flags. The Greenmoor Rock forms escarpments on both sides of the Don and has been quarried at Hartcliff Hill, west of the Tower.

The Better Bed and Black Bed Coals.—The Better Bed Coal is present only in the extreme north. At Dogley Bar and Dean Bottom, Kirkburton, where the seam was worked along the outcrop by means of day-eyes, it was 18 in. thick and rested on 4 ft. 6 in. of good fireclay. The roof of the seam consists of grey bind and mudstone. These workings have been abandoned for many years. Where this horizon is again seen in the Thunderbridge valley the uppermost bed of the Elland Flags has a ganisteroid surface and is overlain by fireclay, while the coal is absent.

In an old quarry at Colne Bank, Height Green, 800 yards north-east of Brockholes railway station, the uppermost beds of the Elland Flags are exposed and the Better Bed Coal is absent, though thin ribs of ganister rock represent the seat-earth of that seam in this area. The full section is as follows:—

		Ft.	In.
	Sandy shale	2	0
	Ganister rock	0	6
	Yellow shaly fireclay	4	0
	Ganisteroid sandstone	0	3
	Sandy shaly fireclay	1	6
	Hard ganister rock	0	6
	Sandy shale	2	6
Elland Flags	Hard fine-grained flaggy sandstone	6	0+

At the eastern end of Thurstonland Tunnel the upper part of the Elland Flags is exposed and consists of alternating bands of thin flaggy shale and ribs of flaggy sandstone not more than 2 ft. thick. Six feet from the top of the Flagstone series is a band of hard ganister-like fine-grained sandstone 4 ft. 6 in. thick, while above the topmost layer of flagstone is a thin coal smut. This is the most southerly point along the outcrop that we have seen coal on the horizon of the Better Bed Coal of West Yorkshire; though at Skelmanthorpe four miles to the east of Thurstonland the coal was passed through in a deep boring for water and was found to be at least three feet thick (see p. 183). In a water boring at the Victoria Mills, 750 yards east of Shepley Church, the Elland Flags were reached and on the uppermost bed was a seam of fireclay about 6 ft. thick, but no coal was present. A fireclay was also found at a corresponding horizon in a water boring at Mill Bank Hall, High Flats.[1]

In a lane section alongside Wood Lane, Shepley, and in the Stone Wood valley, 450 yards south of Stocksmoor railway station, the upper bed of the Elland Flagstones is again seen to be overlain by a thin bed of fireclay. A small quarry at Hillend, one mile south-east of Shepley Church, shows the following section near the top of the Greenmoor Rock :—

	Ft.	In.
Rag	6	0
Mudstone	6	0
Coal	0	2
Fireclay	3	0
Fine massive sandstone (Greenmoor Rock)	35	0+

There appears to be another layer of sandstone above the rag, but the coal and fireclay probably represents the Better Bed: exposures of the same horizons in the quarries at the Sovereign Inn half a mile to the east do not show any coal or fireclay.

The fireclay has been detected at two localities farther south[2]: a boring at the Blue Ball Inn, Thurlstone, showed the following section :—

	Ft.
Grenoside Rock	—
Shale	33
Fireclay	6
Shale	20
Flagstone	—

and at Brock Holes, one mile north-north-west of Midhopestones Bridge, 3 ft. of clay and bastard ganister with a coal smut was seen.

The Black Bed Coal, which is an important seam in the Lower Coal Measures of West Yorkshire, has been worked around Kirkburton, but to the south of Lane Head it dies away in a southerly direction and is unrepresented around Shelley. In the Kirkburton district it is sometimes referred to as the Tinker Coal and is invariably overlain by the rather massive gritty sandstone, known as the Grenoside Rock. The seam has been worked from day-eyes along the eastern side of the railway near Kirkburton Station.

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 129.
[2] *Ibid.*, pp. 128, 129.

Thence it can be traced to Burton Dean and around the northern and western slopes of High Cross, a prominent feature to the south of Kirkburton, capped by the Grenoside Rock.

It has apparently been worked in this area as there is a disused shaft to this coal 350 yards north-west of Kirkburton Church. No details could be ascertained as to the extent and depth of these workings. At Box Ings Collieries, under Shelley Wood, the seam was 18 in. thick with a 3-in. dirt parting in the middle. There is an old shaft to these workings, 90 ft. deep, at Yew Tree Farm, 200 yards south of Kirkburton Church. To the south of here the base of the Grenoside Rock is well exposed on the southern slopes of the Thunderbridge valley and at Shelley Far Bank, but the Black Bed Coal is absent and is unrepresented in the country to the south.

The Grenoside Sandstone.—The Grenoside Sandstone forms a prominent escarpment at Farnley Tyas extending southwards to Farnley Moor and overlooking the Holme valley. From these places it extends eastwards as a plateau with a uniform surface and gentle easterly declination.

There are several disused quarries in this rock around Farnley Tyas. They invariably show a yellowish massive-bedded gritty sandstone, with occasional lenticular partings of sandy micaceous shale. A boring for water at Blagdens, 1,200 yards south of Farnley Church, showed the Grenoside Sandstone to be 30 ft. thick and separated from the underlying Elland Flags by 90 ft. of dark shale.

About half a mile to the north-east of Thurstonland village an outlier of the Grenoside Rock forms a conspicuous feature known as Brown's Knoll. The same sandstone also forms a prominent plateau to the east of Thurstonland, on which the hamlet of Stocksmoor is situated. The rock is well exposed in the railway-cuttings both to the east and west of Stocksmoor railway station, and also in several small disused quarries in the village. It here consists of a rather massive-bedded gritty sandstone.

Along the eastern edge of the Thunderbridge valley the Grenoside Rock gives rise to a well-marked escarpment extending from Hartley Bank (half a mile south-west of Kirkburton) to Shelley Far Bank. There are several disused quarries in it showing the same character as at Stocksmoor.

To the south of the Thunderbridge valley it forms an upland plateau with a uniform north-easterly dip surface on which the village of Shepley is built. It forms a marked feature along the eastern slopes of the Stocksmoor valley. There are numerous disused quarries in the rock around Shepley where it maintains its very uniform character. In a water boring at Victoria Mills, 750 yards east of Shepley Church, the Grenoside Rock was found to be 38 ft. thick.

From its western edge at Pike Lowe the Grenoside Sandstone extends through Low Common and High Flats to the Cumberworth Fault at Denby Dale and, south of the tongue of higher measures at Upper Denby and Ingbirchworth, to the Don valley at Thurlstone. It has been much quarried near Birds Edge, up to 32 ft. of massive sandstone being seen; a well on Low Common, starting below the top of the sandstone, showed 57 ft. of rock. At Thurlstone there are large quarries on both sides of the valley. Hartcliff Tower is built on the edge of the plateau formed by the Grenoside Sandstone, which extends eastwards through Langsett Common.

The Grenoside Sandstone is overlain by a thin coal known as the Grenoside Sandstone Coal. Traces of the coal were seen overlying the Grenoside Rock at Oaklands and Lane Head to the east and south of Kirkburton village, though no good section is exposed. The coal, about six inches thick with several dirt partings, was also observed in a shallow trial boring made in Healey hamlet, 1,000 yards west of Shelley Far Bank. Its outcrop can also be traced from Shelley Far Bank southwards to Shepley village, the bed being exposed in excavations for new buildings alongside the Shelley and Shepley main road. It was only a few inches thick but rested on a bed of fireclay about 4 ft. thick. Traces of the coal have been seen at various points between Birds Edge and Ingbirchworth. In the valley of the Maze Brook, half a mile

south-east of Ingbirchworth Reservoir, 4 in. of coal is seen, and the overlying shales contain *Carbonicola*. In the valley north-east of Cat Hill the Grenoside Sandstone occurs as an inlier between two faults, and the coal has recently been worked from two day-eyes. The coal has also been detected at Edge Hill at the western end of Penistone Common.

The Penistone Flags.—Above the Grenoside Rock comes upwards of eighty feet of shale with bands of hard flaggy sandstone and an occasional layer of ironstone nodules. These are succeeded by a series of flagstones which attain their maximum development in the Penistone district and are hence termed the Penistone Flags.

They are well developed around Skelmanthorpe and Scissett, where they consist of two or three main beds of flagstone separated by shale; the total thickness of the flagstone series in this district is about 120 to 150 ft. The different beds of the Penistone Flag group are often locally referred to as the delf rock or delf flagstones, the name being apparently applied to a fine-grained flaggy sandstone.

In the Kirkburton and Shelley districts the only representatives of the Penistone Flag group are thin sandstones present here and there and sometimes a coal smut. The average section between the Grenoside Rock and the Whinmoor group of coals hereabouts is as follows:—

	Ft.	In.
Whinmoor Coal	—	—
Sandstone, not always present	—	—
Shale	60	0
Thin coal. Penistone Green Coal?	1	6
Shale	25	0
Coal. Lower Penistone Coal?	0	4
Shale	120	0
Grenoside Rock	—	—

The Penistone Flags appear to be first definitely represented immediately below the Low Whinmoor Coal to the east of Kirkburton. Here there is a thin flaggy and impersistent bed of sandstone not more than a few feet thick.

Half a mile due south of Kirkburton Church, a flaggy sandstone with an impersistent parting of sandy shale forms a marked shelf or scarp feature in Cinder Hill and Healey Greave Woods, Shelley. This sandstone is clearly the local representative of the Penistone Flags, but it is limited to the east by the north-west and south-east fault running through Shelley Far Bank to Cumberworth.

The Penistone Flags also form a plateau around Heaton to the east of Shepley; two distinct bands of sandstone can be traced, both consisting of shaly sandstone and rag. Six hundred yards south-east of Shepley Church the lower bed is rather massive and gives rise to low crags alongside a small reservoir. The same bed of sandstone is seen in the railway-cutting 800 yards east of Shepley railway station.

The village of Skelmanthorpe is built on a mass of Penistone Flags which appear to be in three main beds. The greater part of the village is built on the middle bed which is the most conspicuous hereabouts and is exposed alongside many of the lanes, while the lowest beds are well exposed in Thorpe Dike, 800 yards south-east of Skelmanthorpe Church. On the south side of the River Dearne the Penistone Flags also form well-marked step-like features in Bagden Park, the Hall being built on the middle bed. An average section of these beds in the Scissett district has already been given on p. 82.

Some thin unworkable and not very persistent seams of coal occur associated with the Penistone Flags. The most important in the Skelmanthorpe and Scissett area is the Lower Penistone Coal, about 10 in. thick, which immediately overlies the middle or main bed of flagstone and occurs about 120 ft. above the top of the Grenoside Rock.

In the railway-cutting half a mile east of Shepley Station a coal is seen underlying the lower of the two beds of Penistone Flags which occur in the Shepley district. The full section is as follows:—

	Ft.	In.
Coal	0	4½
Clay	1	4
Coal	0	5
Black clay	0	3
Whitish clay	1	0
Ganisteroid sandstone	0	8

Two thin coals which crop out in the beck alongside Brook House Lane, Shelley, 1,000 yards south-west of Shelley Church, also apparently belong to the Penistone Coal group. The higher one is 11 in. thick, while about 20 ft. below it and alongside Brook House the lower one, 10 in. thick, crops out. This rests on a bed of good fireclay, 4 ft. thick, which is underlain by hard ganister rock. The exact position of these seams in the sequence is uncertain.

To the west of Skelmanthorpe a thin coal seam overlies one of the upper beds of the Penistone Flags at Ponker Nook, 300 yards south of Skelmanthorpe Church. This appears to be a local representative of one of the upper coals of the Penistone district.

Several thin and probably impersistent seams of coal are also associated with the main mass of the Penistone Flags in and around Skelmanthorpe village. Thus just to the south of Skelmanthorpe Station two thin seams each about 3 in. thick underlie the Penistone Flags, while 350 yards south of the station a quarry in flaggy sandstone shows a 9-in. seam of coal at the base.

A thin parting of shale in the main mass of the Penistone Flags of Skelmanthorpe village can be traced eastwards from near the church to Pease Field and from thence westward to Thorpe Dike. A thin coal occurs at the base of this shale, and the following section was exposed in Pease Field, nine hundred yards east of the church:—top coal, 6 in.; dirt, 4 in.; coal, 8 in. This may be the local representative of the Penistone Green Coal.

The Lower Penistone Coal is well exposed along the slopes of Thorpe Dike, at Bagden Park and at Scissett, immediately underlying the Middle Penistone Flags. It crops out immediately under Bagden Hall, where the seam runs as follows:—top coal, 8 in.; dirt, 1 ft. 4 in.; coal, 8 in.

Around High Flats and Upper Denby the Lower Penistone Coal is separated from the Grenoside Sandstone Coal by about 50 ft. of shale; here and there attempts have been made to work it opencast or by day-eyes at the crop: it is almost immediately succeeded by a bed of flags, a well at High Flats showing rock 21 ft., shale 3 ft., coal 10 in. The flags have been quarried on both sides of the road at Delf Hills, half a mile south-east of High Flats; 25 ft. of flags are seen in the quarry marked on the map. They are succeeded by mudstones and shales containing the Cumberworth Thin Coal.

South and east of Upper Denby other members of the Penistone Flag Group appear. Near Gunthwaite Hall the succession is:—

	Ft.
Shales with Cumberworth Thin Coal	—
Flags ... ... about	25
Shale ... ... ,,	20
Penistone Green Coal	—
Flags ... ... about	20
Shale ... ... ,,	25
Lower Penistone Coal	—
Flaggy sandstone ... ... about	30
Shale ... ... ,,	—

In the valleys between Nether End and Broad Oak still further members are present as follows:—

A.—CHEESE GATE NAB, HEPWORTH.

B.—RIVER DON NEAR PENISTONE, WITH PENISTONE FLAGS AND PACK-HORSE BRIDGE.

To face p. 95]

	Ft.
Shales with Cumberworth Thin Coal	—
Flags ... ... about	25
Shale ... ... ,,	10
Charlton Brook Coal 5 in., on bastard ganister ...	—
Flaggy sandstone ... ... about	30
Shale ... ... ,,	20
Penistone Green Coal	—
Flags	20
Shale	25
Lower Penistone Coal	—
Flaggy sandstone	30

From Ingbirchworth to Thurlstone the lowest bed of flags forms a wide dip-slope; the Lower Penistone Coal above it is 3 in. thick, being seen in a small outlier of the overlying shale and at the margin of the main mass of higher beds along the east bank of Scout Dike, the stream flowing from Ingbirchworth to join the Don near Penistone. The higher beds form a ridge running from just east of Ingbirchworth to the tunnel (Well House) on the railway; the Lower Penistone Coal is again seen in the railway-cutting at Carr Head, half a mile west of Cat Hill, and is 6½ in. thick.[1] Probably the same coal is seen up to 10 in. thick in Malling Carr Wood between the north end of Well House Tunnel and Cat Hill, but the beds are much faulted and the identification uncertain. East of the railway the Charlton Brook Coal has been seen in a small quarry at the cross-roads on the Penistone-Barnsley road; it was 9 in. thick with 4 ft. of shale and underclay on sandstone; there are three beds of sandstone between it and the Lower Penistone Coal, but the upper two appear to unite just east of the boundary of the map. The bed of flags beneath the latter coal is well seen in the banks of the Don below Penistone, where it is crossed by the fine old pack-horse bridge known as Boulder Bridge (Plate IVB). The general section of these measures at Penistone has been given above; at The Green the Penistone Green Coal was being worked from a shaft 24 ft. deep at the time of the original survey (1870); it was only 9 in. thick.

The Whinmoor Group of Coals.—The Whinmoor Coal first appears as a definitely recognizable seam in a section in Rods Beck, half a mile to the north of Lepton Church. It is here one foot thick and is overlain and underlain by shaly sandstone. South of here and practically along the northern margin of the present one-inch map it splits into two seams, the Top and Low Whinmoor, while at Hallas, half a mile north-east of Kirkburton, a dirt parting further separates the Top Whinmoor into an upper and lower bed.

In this district the Shertcliffe, Black Band or ' Beeston ' Coal lies 27 to 30 ft. above the topmost Whinmoor seam, the intervening measures consisting of shale and shaly sandstone. The full section to the north-east of Kirkburton is given above (p. 84.) In the country between Kirkburton and Royd House the Shertcliffe or Black Band, the Top Whinmoor and the Low Whinmoor coals have all been worked along the outcrop from a succession of day-eyes.

The Low Whinmoor can be traced from the east of Oaklands, Kirkburton, southwards to the southern end of Shelley Wood; it is here known as the Low Lousey, the Top Lousey being another unimportant seam in the measures above the Whinmoor group. South of here it cannot be definitely recognized in the Shelley district. The seam with much dirt and about 12 in. thick was seen in a road-cutting alongside Wood Nook Farm, 1,200 yards north-west of Shelley Church. To the north of Wood Nook Farm, where it has been tried along the outcrop, it was from 10 to 12 inches thick, and rested on 3 ft. to 3 ft. 6 in. of excellent fireclay which has been mined on a small scale.

[1] ' Geology of the Yorkshire Coalfield ' (*Mem. Geol. Surv.*), 1878, p. 573.

The Cumberworth Thin Coal overlies the uppermost bed of the Penistone Flags and averages 1 ft. 3 in. in thickness. It is mainly worked at Lower Cumberworth and Denby Dale for the valuable bed of fireclay which underlies it. It is usually separated by upwards of 30 ft. of shale from the Main or Top Whinmoor Coal and corresponds to the Low Whinmoor Coal of the Shelley and Kirkburton district. This seam can first be definitely recognized as such at Cliff Hill, Cumberworth, to the south of the main Skelmanthorpe east-and-west fault. From Cliff Hill it can be traced south to Ponker Hill and to the head of Thorpe Dike hollow in the village of Lower Cumberworth. At Ponker Hill a thin sandstone occurs in the measures above the Cumberworth Thin Coal. The coal is hereabouts 1 ft. thick, and is being worked along the outcrop solely for the fireclay which underlies it. The fireclay, 4 ft. 6 in. thick, is employed at the Cumberworth Brick and Tile Works for the manufacture of pipes, tiles and other goods.

At Denby Dale the Cumberworth Thin Seam is being actively worked for fireclay on the west of the railway between the station and the tunnel; the section is coal 1 ft. 3 in., clay 4 ft. South of the valley the Denby Fireclay Company have recently opened a pit a quarter of a mile east of Upper Denby Church : the clay is again 4 ft., overlain by 1 ft. of coal with dirt. In the valley just south of Lower Denby, both fireclay and ganister are obtained, the section being coal 14 to 16 in., ganister about 2 ft. 6 in. and clay 4 ft. In many of the workings in this district the coal is left in as a roof for the fireclay. Southwards towards Gunthwaite Hall the measures between this seam and the Whinmoor become almost entirely sandstone, but the flags between it and the underlying Charlton Brook Coal die out. Farther south a similar succession comes in at Cat Hill, but is then cut off by an east-and-west fault.

The Top or Main Whinmoor Coal, usually referred to simply as the Whinmoor and sometimes as the Cumberworth Three Beds Coal, is of economic value throughout the district. At Green House Collieries, 500 yards south-west of Royd House this seam and the overlying Black Band or Shertcliffe Coal are both worked, the measures between being 33 ft. of shales or thin shaly sandstone.

At the Standing Hirst pit shaft, 700 yards south-west of Royd House, the following was the succession of these coals and the measures associated with them :—

		Ft.	In.
Thin coal band		—	—
Measures		84	0
Black Band Coal		1	6
Measures		33	0
Whinmoor Coal	Coal	0	6
	Dirt	1	0
	Coal	1	2
	Dirt	4	0
	Coal	1	2

The Black Band or Shertcliffe is here referred to as the Top Bed.

During the re-survey of this district the Top Whinmoor was being worked at Red Hill Colliery, Shelley, 1,000 yards west-north-west of Shelley Church, and the section here ran as follows :—

	Ft.	In.
Coal and shale mixed	5	0
Blue shale	12	0
Coal	0	9
Shale	1	2
Coal	1	2

From Red Hill the outcrop of the Whinmoor can be readily followed through Shelley village where it has been worked in many places. It is here overlain and underlain by flaggy sandstone. There are old crop-workings

alongside the Manor House and both to the north and south of Shelley Church. A quarry has been opened in the sandstone underlying the coal in Woodhouse Field, 300 yards south-east of Shelley Church, and shows 15 ft. of well-laminated flaggy sandstone. The sandstone which underlies the Whinmoor Coal rests on a thick series of shaly mudstones and consequently gives rise to a marked escarpment in Shelley village, the latter being built on the shelf or plateau formed by the rocks: whence the name Shelley (Shelf-Lea).

At the eastern end of Shelley village the Whinmoor (strictly the Top Whinmoor) is further split up by dirt partings and the following is a section of the seam in crop-workings alongside Bark House Lane, 150 yards north of Shelley Church :—

	Ft.	In.
Coal	0	6
Dirt	1	0
Coal	1	2
Dirt	4	0
Coal	1	2

The 4-ft. dirt parting varies very considerably in thickness, and in places around Shelley it reaches 30 ft. in thickness.

A line of old crop-workings in the Whinmoor Coal occurs one hundred yards south of, and parallel to, Green House Lane, Shelley. One thousand yards north-east of Shelley Church these workings end abruptly against the important fault which runs north-west and south-east from Kirkburton past Royd House to Skelmanthorpe.

The Whinmoor Coal crops out in the Park Gate valley to the north of Skelmanthorpe and has been worked somewhat. Alongside Park Gate Terrace the following was the section of the seam: top coal, 1 ft.; dirt, 10 in.; bottom coal, 2 ft. There are also numerous disused workings in this seam along both sides of Park Gate Dike at Blacker Wood.

To the south of Shelley, Skelmanthorpe and Clayton West the Whinmoor and associated coals have been worked at Lower Cumberworth and to the south of Scissett. The Black Band (or Shertcliffe) and Whinmoor coals both crop out in the small valleys at Wood Nook north of Shelley and at Brogg Wood about a mile east of Shepley railway station; they occur at a comparatively shallow depth in the whole of the Cumberworth district and have been extensively mined.

At Wood Nook the details of the Whinmoor Seam are as follows:—

	Ft.	In.
Coal	1	2
Sandy shale	1	0
Coal	1	3
Shale	0	10
Coal	1	5

The two dirt partings extend over considerable areas, wherefore the coal is often called the Cumberworth Three Beds Seam; the general section of the measures here is given above (p. 84). Five hundred yards east of these collieries and on the eastern side of the Huddersfield-Penistone railway the coals have been worked at Kirkstyles Colliery; the bottom bed of the Whinmoor Coal is here 1 ft. 8 in. and the total with the two dirt partings 6 ft. 3 in.

The Whinmoor Coals and the measures associated with them exhibit rapid lateral variations in thickness and character in this area. Thus in the adjacent colliery workings at Ings or Ozzings, alongside the junction of the Clayton West branch railway with the main Huddersfield-Penistone line the section of the Whinmoor Seam was as follows :—

		Ft.	In.
Whinmoor Coal	Coal	0	9
	Dirt	1	0
	Coal	1	3
	Dirt	1	2
	Coal	1	4

There were numerous small faults in these workings. All the workings in the Whinmoor and Black Band coals are limited to the north by an important east-and-west fault which can be traced from the junction of the Clayton West branch railway with the Huddersfield-Penistone main line, past Barncliff Hill and Cliff Hill to Skelmanthorpe. The actual position of the fault was located in workings in the Whinmoor Coal at Cliff Hill. From Cliff Hill the outcrop of the Black Band and Whinmoor coals can readily be traced southwards across Cumberworth Common to Lower Cumberworth village by means of a succession of disused crop-workings.

At Cumberworth Colliery, quite close to the Inn at Lower Cumberworth (see one-inch map), both the Black Band and the Whinmoor coals were worked along the outcrop about twenty years ago. The following was the section of the seams :—

		Ft.	In.
Blue bind		—	—
Black Band Coal		2	1
Shale		—	—
Blue bind		—	—
Whinmoor Coal	Coal	0	11
	Dirt	1	4
	Coal	1	4
	Dirt	1	1
	Coal	1	6
Bind and shale		—	—

Just south of Lower Cumberworth village, the Whinmoor Coal has been worked at Leak Hall Colliery, and here the average section of the seam was as follows :—

		Ft.	In.
Rock		—	—
Dirt		0	8
Whinmoor Coal	Coal	1	2
	Dirt	0	8
	Coal	1	4
	Dirt	0	8
	Coal	1	5

The Whinmoor Coal has also been extensively worked to the south and east of Scissett at Nortonthorpe Colliery. It was worked by means of a series of day-eyes along the outcrop alongside Lower Common Lane and in Bagden Wood, and also by mining under Wheatley Hill. The seam ran as follows at Nortonthorpe :—

		Ft.	In.
Stone bind		24	0
Whinmoor Coal	Coal	0	8
	Dirt	0	4
	Coal	1	8
	Dirt	1	3
	Coal	1	6
Fireclay		—	—

Half a mile south of Clayton West village, the Whinmoor Coal has been worked both along the outcrop and also by mining in Riding Wood. The following was the detailed section of the seam at a day-eye in Riding Wood :—

		Ft.	In.
Whinmoor Coal	Coal ... ... 7 to		8
	Black coaly shale ... ... 4 to		6
	Coal	1	2
	Grey clay with black shale layers ...	2	1
	Sulphurous coal	0	4
	Coal	1	1
	Clay and coal	0	6
Fireclay		0	3
Sandstone with Stigmarian rootlets		—	—

A boring at Upper Common, Clayton West, 300 yards south of Riding Wood Lodge, is of interest as giving the distance in this area between the Whinmoor and Black Band coals:—

		Ft.	In.
Measures		52	5
Black Band Coal		1	7
Measures		24	0
Whinmoor Coal 6 ft. 8 in.	Coal	1	2
	Dirt	0	6
	Coal	1	7
	Dirt	2	2
	Coal	1	3

From Riding Wood the outcrop of the Whinmoor can be traced through the hamlet of Spring Grove to Clayton West Station. An excavation near the railway station proved the Whinmoor Coal close to the surface in three thin seams, separated by dirt partings.

Around Denby Dale the Whinmoor Coal is largely worked from surface mainly in connexion with the Thin Bed fireclay; it is usually overlain immediately by a sandstone. A quarter of a mile west of Denby Dale Station a section is as follows:—

	Ft.	In.
Sandstone	—	—
Rubble	2	0
Coal	0	10
Dirt	1	2
Coal	1	3
Dirt	0	9
Coal	1	8
Fireclay	—	—

East of the railway there are a few shafts to this coal, up to about 30 ft. deep. East of Nether End the seam appears to be washed out. It is succeeded by about 50 ft. of sandstone and the same of shale before the Black Band is reached.

The most southerly appearance of the Whinmoor Coal within our area is at Cat Hill and Hoyland Swaine Heights, the ridge running slightly south of east from there. It has been worked from day-eyes and shallow shafts and has a thickness of 2 ft. 6 in. The Black Band or Shertcliffe Coal which occurs about thirty feet above the Top Whinmoor to the east of Kirkburton, and is sometimes called the Beeston Coal in this district, has been worked along the outcrop between Shelley and Royd House. At Green House Collieries, 500 yards south-west of Royd House, where it was 18 in. thick, it was mined at a depth of 84 ft.

The main Skelmanthorpe Fault which runs from north-west to south-east from Kirkburton past Royd House and through Skelmanthorpe to Wheatley Hill has a considerable downthrow to the north-east, and the Black Band Coal is exposed on the east side of this fault in Rough Piece Wood Hollow, about 800 yards south-east of Royd House. It has been mined somewhat here and runs as follows: top coal, 9 in.; dirt, 4 in.; bottom coal, 9 in. Below the coal is a great thickness of shaly mudstone with layers of ironstone nodules and occasional bands of thin flaggy rock;

the beds roll considerably and dips of 20 degrees and more are frequent. The outcrop of the Top or Main Whinmoor could not be definitely located and may be cut out by faulting, the sections in the lower part of the Hollow being very obscure.

The Black Band Coal, 19 in. thick, was observed in an old overgrown quarry close by the coke-ovens at Emley Moor Collieries, 150 yards north of Skelmanthorpe railway station. In this area it is about 21 feet above the Whinmoor Seam. At Kirkstyles Colliery (see above) the Black Band Coal is 1 ft. 8 in. thick and rests on a stiff blue fireclay. At Barncliff Hill it is 1 ft. 10 in. thick and was mined from several shafts varying in depth from 20 to 60 ft.; the measures here have a uniform dip of 1 in 18 to the west; the seam was also worked at Cliff Hill Colliery.

North of Clayton West railway station there is an important east-and-west fault with a downthrow to the north bringing in the Middle Coal Measures. In this area and just along the eastern margin of the area shown on the map, the Shertcliffe or Black Band Coal has been reached in sinking at the Park Mill Collieries, Clayton West. Park Mill Collieries are five hundred yards due north of Clayton West railway station. The Blocking or Silkstone Coal occurs at a depth of 204 feet, and 92 ft. 5 in. below this seam occurs the Black Band or Shertcliffe, 1 ft. 10 in. thick. To the south of the Dearne valley the Black Band has been worked to a small extent and its position is clearly marked by the overlying sandstone.

From the Black Band to the Blocking or Silkstone Coal.—In this district in the measures between the Whinmoor and Silkstone coals there occur several thin seams of coal, the most important of which appear to be two seams known respectively as the Little Coal or Low Lousey, and the Top Lousey, sometimes referred to simply as the Lousey. Neither of these seams are of sufficient value anywhere to be worth working.

The Little Coal is represented in practically all the sections of these measures between Thornhill, Lepton and Clayton West. It occurs at a short distance, varying from eight to twenty feet, above the Black Band or Shertcliffe Coal.

The Top Lousey Coal appears to correspond to the Lousey Coal of the Whitley and Lepton districts.[1] South of the Dearne valley the measures between the Silkstone and Black Band coals are reduced to about 25 feet in thickness with traces of coals, which are exposed in stream sections but cannot be followed.

At Park Gate, north of Skelmanthorpe, there occurs a coal locally known as the Lousey Coal which overlies a thin bed of sandstone. It was exposed in the lane running from Emley to Park Gate at a point 600 yards north-east of Skelmanthorpe railway station and ran as follows:—tops, 2 in.; dirt, 4 in.; coal, 6 in. The same seam is also seen in a steep gully in Emley Park, 500 yards west of Emley Lodge.

A strong bed of shaly rock or sandstone overlies the Black Band Coal in the Lower Cumberworth district; it frequently contains many thick shale partings and ranges up to 40 ft. in thickness in places. Above this sandstone comes a thick series of shaly mudstones with occasional layers of ironstone nodules. These are being worked for the manufacture of bricks at Lower Cumberworth. A drift of 1 in 3 made in Cumberworth brick-yard at Lower Cumberworth down to the Black Band Coal gave the following section of these measures:—

	Ft.
Clay, shale, etc.	36
Bind	6
Stone	5
Bind	7
Stone	6
Shale	5
Black Band Coal	2

[1] See 'Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 88.

In the Scissett district the measures above the Whinmoor Coals are seen in Bagden Park and on the hill-slopes between Wheatley Hill and Clayton West. The following is a section of these measures in the upper part of the brook which runs through Bagden Wood and to the south of Bagden Hall :—

	Ft.
Coal in two beds. ? Lousey	—
Sandstone	20
Thin coal seam	—
Measures	25
Black Band Coal	—
Measures	45
Whinmoor Coal...	—

A day-eye in Bagden Wood gave the following section of the Lousey seam : coal, 2 ft. ; dirt, 9 in. ; coal, 9 in.

In the country between Bagden and Clayton West the Blocking or Silkstone Coal is invariably underlain by a thick bed of sandstone. Immediately below the sandstone occurs a thin seam of coal which can be traced from Bagden to Clayton West, and is imperfectly exposed in Riding Wood half a mile south of Clayton West. In its general position in the sequence it appears to correspond to the Lousey Coal described above.

A complete section of the measures between the Blocking or Silkstone Coal and the Black Band or Shertcliffe Coal was obtained in a trial sinking at Park Mill Collieries, Clayton West. The Blocking or Silkstone Coal occurs at a depth of 204 ft. From this depth the sinking began. It will be observed that several thin and unimportant seams of coal occur in these measures :—

	Thickness Ft.	In.	Depths below Blocking (or Silkstone) Coal Ft.	In.
Blue bind	3	0		
Grey rock	4	6		
Blocking (or Silkstone) Coal	0	4		
Black shale	4	0	4	0
Blue bind	1	8	5	8
Black shale	4	6	10	2
Coal, ? Lousey	0	6	10	8
Blue bind with ironstone bands	30	0	40	8
Coal, ? Lousey	0	4	41	0
Fireclay	9	0	50	0
Strong blue bind with ironstone bands ...	21	0	71	0
Coal, ? Lousey	0	3	71	3
Blue shale	4	0	75	3
Grey rock	12	0	87	3
Black shale	1	0	88	3
? Little Coal: Coal	0	3	88	6
Fireclay	0	1	88	7
Coal	0	8	89	3
Fireclay	1	1	90	4
Coal	0	1	90	5
Hard white bind with ironstone	8	0	98	5
Coal, Shertcliffe or Black Band	1	10	100	3

South of the Dearne valley the high ground north of Lower Denby and Nether End is capped by the sandstone which overlies the Black Band Coal. An old quarry shows 10 ft. of fine sandstone with many irony concretions and ' mare-balls.' North of the fault which brings in the Middle Coal Measures on the high ground the identification of the seams is uncertain ; what appears to be the Black Band Coal is overlain by a sandstone 25 ft. thick above which is the Silkstone Coal.

The Western Areas

Cheshire.—The northward continuation of the syncline known as the Goyt Trough passes through Mottram towards North Britain, south of the east-west Mottram Fault. This syncline is occupied by Lower Coal Measures stretching as far as Fernilee, while the flanks are of Millstone Grit.

The coals and measures of this area are in general similar to those of the adjoining Lancashire-Cheshire Coalfield. The succession present is as follows:—

	Ft.	In.
Sandstone	—	—
Shale ... ...approx.	30	0
Bassy Mine or Lower Yard Coal	2	7
Sandstone, Woodhead Hill Rock ... ... 35 to	45	0
Shale ... ...approx.	100	0
Coal, Six Inch Mine ... ... to		1
Rough Rock	—	—

The above does not include all the measures occurring in the Mottram district, as the horizons there have not been determined. It is probable that the above succession would need to be extended upwards to include the measures in question.

The Six Inch Mine and the Subcrenatum marine band.—Hurstclough Brook, the stream running southwards along the west side of Broadbottom, provides the only exposure of the measures immediately above the top of the Millstone Grits.

The Rough Rock, dipping south-south-eastwards, disappears beneath Coal Measures at a point 430 yards north of the railway embankment which crosses Hurstclough. Both the coal, the Six Inch Mine, and its associated marine band, the Subcrenatum band, are represented. The exposure is in the lane which crosses the brook at that point, the coal ranges from a smut to a thin seam one inch thick.

On the north-east, the upthrow side, of the Hattersley Fault the two complementary outcrops of the Rough Rock are at Hillend and just above the village of Broadbottom itself. In neither case is the junction of the grit and Coal Measures to be seen. A similar state exists on both sides of the River Etherow from the railway viaduct upstream to the Print Works. There the Rough Rock, having been faulted down by the Viaduct Fault, forms the sides of the river gorge, but its top is overgrown and obscured by vegetation and drift.

East of Mottram the base of the Lower Coal Measures runs along the Etherow valley and is obscured by drift and alluvium. The Six Inch Mine and the top of the Rough Rock were encountered in an excavation for foundations on the east bank of the river, 470 yards west-south-west of Melandra Castle.

Measures between the Six Inch Mine and the Woodhead Hill Rock.—Roughly 100 ft. of shale separates the Rough Rock from the next change in lithology, the incoming of the Woodhead Hill Rock. These shales are partially exposed in the Hurstclough between the outcrop of the Rough Rock and the railway. They vary from black to blue-grey shales and contain bands of mudstone and some sandy beds.

Woodhead Hill Rock.—The base of this sandstone reaches stream-level 400 yards south-west of Hillend, and thence to the railway embankment shown on the southern boundary of the map both sides of the clough are cut

in this sandstone. The rock is at least 35 ft. thick and possibly reaches 45 ft. An old quarry on the west side of the clough close to the embankment over the stream shows 27 ft. of irregularly-bedded fine-grained sandstone with occasional current-bedding. In the clough itself the sandstone contains shaly siltstone partings at intervals. It is too irregularly bedded to be used for other purposes than rough walling material.

The Woodhead Hill Rock occurs south of the Hattersley Fault, forming the southern part of Hurstclough. It is there seen to be dipping steeply to the south-south-east.

Between the Hattersley and Viaduct faults the rock caps the top of the ridge, but is not exposed except in ditches. The Viaduct Fault throws the outcrop down about 60 ft. on the north-eastern side, causing the rock to form a steep feature above and parallel to the river gorge in the Rough Rock, extending as far as the Print Works Fault. The outcrop on the other side of the Mottram-Broadbottom ridge is bounded by faults and forms a part of the flattened ridge-top.

Bassy Mine.—The Woodhead Hill Rock is succeeded by the Bassy Mine or Lower Yard Coal from which it is separated by two to six feet of shale and a thin seat-earth. The seam crops out along the edge of the eastern side of Hurstclough from the Hattersley Fault down to the railway embankment. It has been worked at outcrop along this stretch; the thickness of the seam is said to be between 2 ft. and 2 ft. 6 in. Between the Hattersley Fault and the Viaduct Fault the highest bed is the Woodhead Hill Rock; consequently the coal is not present, but north-east of the latter fault the downthrow brings in the Bassy Mine, forming an outcrop ringing the hill-top. A small fault crosses the centre of this outlier, throwing the coal down about 10 ft. to the south. The coal has been worked at outcrop and was proved to be 2 ft. 7 in. thick. Coal has been worked in the area around Mottram between the Mottram and Print Works faults, as the old shafts scattered about bear witness. But none has been got recently, and there are no records of the old workings extant.

Measures above the Bassy Mine.—Above the Bassy Mine only 40 ft. of strata are exposed in this area south-west of the Print Works Fault. Thirty feet of shale followed by a thin sandstone crop out on the south-west side of the Hattersley Fault around the church. The shales, which are mainly black, are partially exposed in the railway-cutting immediately west of the station, as also is the base of the overlying sandstone. Not more than 20 ft. of this shale forms the cover to the Bassy Mine in the faulted outlier of that coal between the Print Works and Viaduct faults.

Several faults cross the area north of the Print Works Fault and exposures are scarce. Practically the only exposures of use are small ones in the stream which runs north-eastwards on the south-east side of Mottram Church. Two of these show the presence of a coal seam; the section at a point 300 yards south-east of Mottram Church is:—

	Ft.	In.
Flaggy sandstone	4	0
Buff shale	2	0
Coal, with thin partings near top	1	5
Grey seat-earth grading into grey shale and mudstone with some siltstone	30	0

A little farther upstream a more detailed section of the coal was obtained:—

	Ft.	In.
Coal	0	3
Clay parting	0	1
Coal	0	2½
Clay parting	0	1
Coal	1	0

In the absence of evidence as to its stratigraphical position this coal has not been identified, but it is certainly higher in the sequence than the Bassy Mine.

It appears to be overlain by a thin sandstone and to have another sandstone not more than 30 ft. below it in the succession. The latter forms the hill-top on which Mottram Church stands.

An outcrop of the Six Inch Mine and some of the overlying shales just comes into the map at its western edge south of Stalybridge. There are no exposures, but the coal and marine band are known to be present in this area.

Yorkshire.—To the west of Thurston Clough and Wall Hill (on the extreme edge of the map) there is a small patch of Lower Coal Measures. The part of the succession represented is that from the base to the Woodhead Hill Rock.

A rough section of the strata is as follows :—

	Ft.
Woodhead Hill Rock : sandstone and flags	75
Shales ... ... 50 to	60
Six Inch Mine : coal with fireclay	—
Rough Rock	—

The area lies to the west of the Greenfield Fault, but is bounded by that fault only at Wade Hill, the remainder of its boundary being that of the normal outcrop. Two small faults intersect the outcrop, one at the north end, the other at the south, but their throws are small.

No sections of the Six Inch Mine and its fireclay are visible, but the coal has been worked from adits at Thurston Clough, though probably the fireclay was more valuable than the coal.

The black fossiliferous shales of the Subcrenatum marine band lie close above the coal ; specimens of these shales are present on the old spoil heaps.

The shales between the coal and the Woodhead Hill Rock are exposed only in ditches to the west of Wade Hill. They contain a thin bed of fireclay.

The Woodhead Hill Rock has been quarried on a large scale south-west of Thurston Clough. The quarry sections show up to 45 ft. of a medium-grained, evenly bedded brown micaceous flagstone which also contains some massive beds. It was used for building stone, walling stone, flags, etc. The complete thickness does not occur at this outcrop, but it is well over 80 ft.

CHAPTER IV

MIDDLE COAL MEASURES

Introductory

The beds assigned to the Middle Coal Measures cover a comparatively small area shown in the north-eastern corner of the present one-inch map. There is a small patch not more than one and a half miles in extent east of Kirkburton and north of Clayton West, while south of the latter village and east of Denby Dale there is another small triangular-shaped area about one square mile in extent. These measures, however, include several important coal seams which have been extensively mined to the north and east. The intervening measures consist largely of shale and mudstone with several impersistent bands of sandstone.

The base of the Middle Coal Measures is taken by general consent at the horizon of the Silkstone or Blocking Coal, but as has been already pointed out elsewhere, this line of demarcation is a purely conventional one.[1] It marks no break or change in the succession either lithological or palaeontological, and does not correspond with the conventional line adopted as the base of the Middle Coal Measures in the adjacent coalfields of the west Pennine areas.

The more important coals which have been largely worked are the Blocking or Silkstone, the Wheatley Lime, New Hards, Old Hards or Parkgate, and the Flockton Thick and Thin seams. All these coals, however, show considerable variation when followed from the Emley district to the south of the Dearne valley and Clayton West. Thus the Blocking and Flockton Thin seams become too thin to be workable while all the other coals show marked deterioration.

The change which takes place in the character of the measures in the country between Emley and Silkstone is by no means confined to the beds we are here describing, but also marks the latitude of an abrupt change at other horizons.[2] This area lies between what may well be termed the West and South Yorkshire coalfields or areas. On either side of this belt of country the majority of the seams have also been given different names, though the general succession of the coals is closely similar. The late Professor Green was fully cognisant of this change and stated that "it is curious that all the coals from the Silkstone to the Park Gate should apparently fall off in quality and change so totally in

[1] 'The Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 48.

[2] Wray, D. A., 'The Barnsley Coal and its variations,' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 127-137.

character in crossing this tract, and it looks as if the conditions, whatever they may have been, that caused the change were repeated during the growth of each one of the seams of coal in this group."[1] His statement can now be extended to cover the Lower Coal Measures and at least part of the Millstone Grits (pp. 127, 128).

At the time of the original survey of this area by Green and his colleagues, the several coal seams to the south of Clayton West, being of relatively poor quality, had been little worked; but a tentative correlation was adopted of this area with the succession in the country to the north and south of it. Since then, however, several of these seams have been exploited and it is now possible to trace with fair certainty the several horizons from north to south.

For the purpose of comparison and correlation the Flockton Thick Coal furnishes the most convenient and reliable datum line. This seam with the very distinctive band of ironstone above it known as the Tankersley Ironstone is well developed both in the Emley and Silkstone districts, and also in the country between Clayton West and High Hoyland, one mile to the east-south-east. Its identity throughout the whole area is clear and generally agreed upon, there being an almost continuous line of workings in this bed from the neighbourhood of Flockton and Emley to Silkstone and Barnsley. The distinctive and well-marked Tankersley or Mussel Shell Ironstone which everywhere occurs a short distance above the coal also contains a distinctive fauna which has been found at Emley, Litherup Lane and Dodworth to the north of Barnsley. The forms which are most abundant include *Carbonicola regularis* Trueman, *C. phrygiana* W. B. Wright, *C.* cf. *aquilina* and *C.* cf. *rhomboidalis* Hind.

In a boring at Emley Moor, the Blocking Coal, 1 ft. 5 in. thick, occurred at a depth of 171 ft. 6in. below the Flockton Thick Coal.[2] Similarly in the Barnsley district the distance from the Flockton Thick Coal to the seam universally known south of here as the Silkstone is 150 ft. The nearest measured section to the area we are now dealing with is at Church Lane Colliery, Dodworth (see Fig. 11). The Silkstone Coal here runs as follows:—top coal, 2 ft. 2 in.; dirt, 6 in.; coal, 1 ft. 11 in.; and seat coal, 3 in. There seems very little doubt that the Silkstone and Blocking coals which occur at such closely corresponding positions in the succession in the Barnsley and Emley districts are, if not exactly the same seam, very closely correlative with one another. Similarly, in the measures between the Flockton Thick and Blocking coals at Emley Moor there occur five principal seams which in descending order are known respectively as the Flockton Thin, the Old Hards, the Green Lane, the New Hards and the Wheatley Lime.

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 281.
[2] *Ibid.*, p. 353.

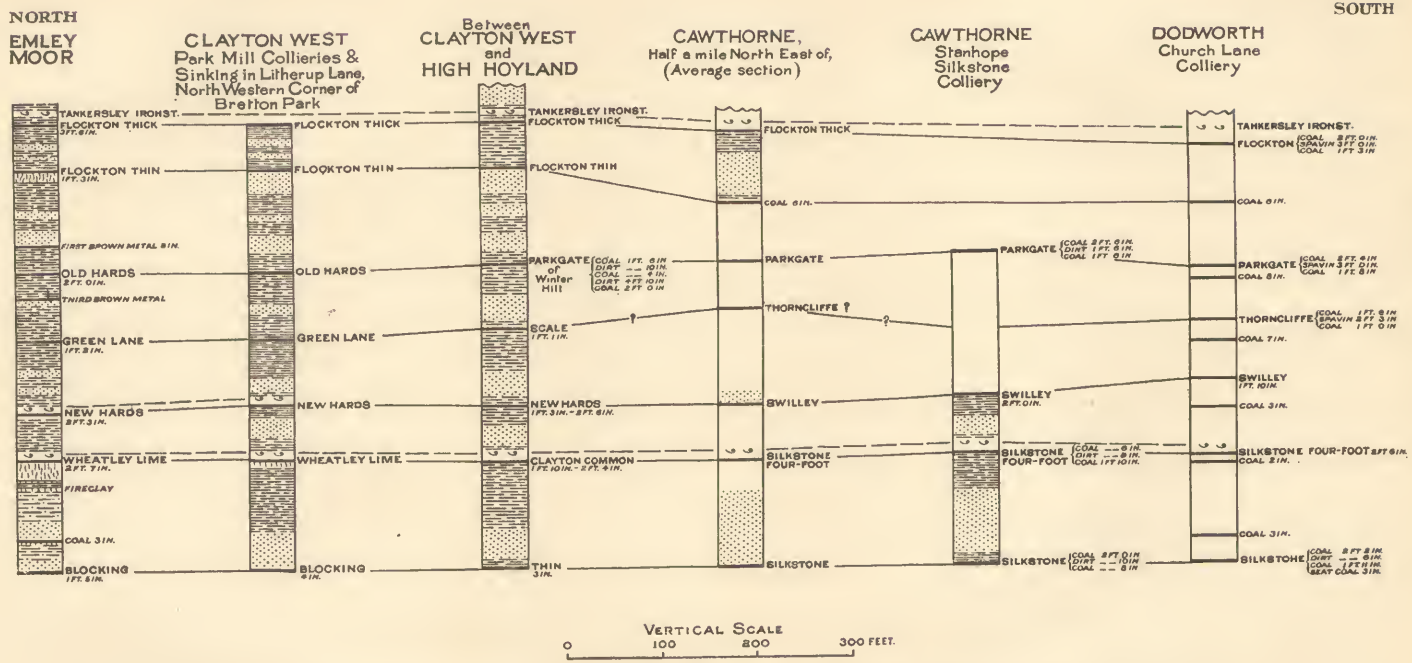

FIG. 11.—*Comparative sections of the measures between the Silkstone and the Flockton Thick coals.*

At the Church Lane Colliery, Dodworth there are also five seams in corresponding positions in the sequence which in descending order are known respectively as the Eight-inch, Parkgate, Thorncliffe, Swilley and Silkstone Four-Foot. Although therefore we are unable to trace these seams individually from the vicinity of Emley continuously along the outcrop to the Barnsley district there seems no doubt about the general correspondence of the succession of the seams, though different nomenclature has been adopted in West Yorkshire and South Yorkshire (cf. Fig. 11). The close correspondence of these successive coals in each area is still further supported by several other features. Thus the Parkgate and Swilley seams of the Barnsley district are of a very similar nature to the Old Hards and New Hards seams respectively of the Emley district. So close in fact are their general resemblances that in several workings in each area, either name is applied indiscriminately to the seams.

Again, not only does the Wheatley Lime strongly resemble the Silkstone Four-Foot Seam in general characters, but in addition the measures associated with both seams are very similar. A well marked *Carbonicola* band is associated with the Wheatley Lime Coal at Emley and is indistinguishable in general appearance from that associated with the Silkstone Four-Foot at Dodworth; the fauna is the same and includes the following distinctive assemblage: *Carbonicola pseudorobusta* Trueman, *C. decorata* Trueman, *C.* cf. *communis* Dix and Trueman, *C.* cf. *rhomboidalis* Hind, *C.* cf. *ovalis* (Martin), *C.* cf. *subconstricta* (J. de C. Sowerby), and *C.* cf. *rhindi* (Brown), together with *Naiadites* cf. *carinata* (J. de C. Sowerby) and *Naiadites* cf. *producta* (Brown).

The correlation given above is in accord with that originally adopted by Green,[1] and the re-survey of the area has fully upheld Green's original tentative correlation. In the intermediate area, however, around High Hoyland, recent work suggests a modification of the correlation put forward for this area by Professor Green in 1878.[2] Thus the Blocking Coal, which was tentatively correlated by Green with the seam known in the country between Clayton West and High Hoyland as the Clayton Common Coal, appears to correspond more closely with a thin coal about 115 ft. below. The Clayton Common Coal, which has since been worked somewhat extensively along the outcrop, exhibits marked resemblances to the Wheatley Lime and Silkstone Four-Foot seams. The measures associated with it are also very similar and include the distinctive *Carbonicola* band referred to above. The correlation of the 'Scale Coal' and 'Unknown Coal' of the Clayton West and High Hoyland district with the Green Lane or Thorncliffe and Swilley or New Hards seams respectively is also supported by our investigations (see Fig. 11).

[1] Green, A. H., *op. cit.*, p. 245.
[2] *Ibid.*, pp. 280, 281.

The Blocking Coal which is a good workable coal throughout the greater part of West Yorkshire falls off considerably in quality in the Emley district and is not worth working to the south of here, except at Exley Gate (see below). While it maintains an average thickness of about 18 inches to the north of Emley it was found to be only six inches thick at the Standbacks Shaft, 1,200 yards south-west of Emley Church. At Park Mill Collieries it is only four inches thick, and between Clayton West and High Hoyland it becomes a mere smut. Where next seen at Cawthorne what we believe to be the same seam is known as the Silkstone and is thin with many dirt partings. These latter die away gradually as the seam is traced southwards, and it then constitutes the highly important Silkstone Seam of South Yorkshire.

The Wheatley Lime on the whole maintains a more constant character. In the Emley district it ranges from 18 in. to 2 ft. in thickness, and at Park Mill Collieries is as much as 2 ft. 8 in. in thickness. On the southern slopes of the Dearne valley it has been mined along the outcrop at Back Lane Colliery, 500 yards south of Park Mill Collieries, and here though somewhat inferior in quality averaged 2 ft. 2 in. in thickness. What is undoubtedly the same seam, though termed the Clayton Common Coal, has been worked along the outcrop between Hoyland Bank and Wheatley Hill where it averages 2 ft. 3 in. in thickness.[1] It has also been mined at Upper Bagden, half a mile south of Wheatley Hill. The next appearance of this bed is in the Cawthorne district and according to Green, a coal which is most likely this bed crops out on the road a little above Cliff Hill Bridge, Cawthorne, where it runs as follows :—black shale; coal, 1 ft. 3½ in.; light grey clay with seams of coal, 6 in.[2] In a boring a little to the north of here it was stated to have been 2 ft. 1 in. thick, while a boring at Cinder Hill showed it to be 2 ft. 7 in. thick with a 2-inch dirt parting.[3] To the south at Falconer Colliery and Dodworth it averages 2 ft. to 2 ft. 6 in. in thickness and is known throughout the country to the south as the Silkstone Four-Foot.

The New Hards Seam is at present being somewhat extensively mined at Park Mill Collieries, where it averages 3 ft. in thickness, with a dirt parting about 14 in. thick in the middle of the seam. The workings have extended for upwards of a mile in a south-easterly direction. Between here and Hoyland Bank the same seam (the ' Unknown ' Coal of Green's succession)[4] has been worked along the outcrop. It is somewhat thinner here and has deteriorated in quality considerably; it has also been worked at Pool Hill and in Deffer Wood. South of here in the country to the north-west of Barnsley it shows very rapid fluctuations in thickness and is consequently known as the Swilley Seam. While in some places it is only 1 ft. 10 in. thick on an average, and in others

[1] For much valuable information on the succession in this area we are indebted to Mr. H. Auckland of Clayton West.
[2] Green, A. H., *op. cit.*, p. 256.
[3] *Ibid.*, p. 256.
[4] *Ibid.*, p. 280.

absent altogether, it was found in places at Dodworth to attain thicknesses of from 4 to 5 feet.

The Green Lane Coal is always thin, but apparently fairly persistent. The 'Scale Coal' of Clayton West and High Hoyland which is a mixture of coal and shale totalling about 1 ft. in thickness corresponds exactly to the Green Lane of the Emley district (see Fig. 11). In the Cawthorne district it appears to be split by about 13 ft. 8 in. of measures. This parting thins away and dies out in a southerly direction.[1]

The Old Hards or Parkgate is almost invariably known as the Parkgate in the country to the south of Emley. It exhibits no marked variations though dirt partings are frequent in the seam in the Clayton West and High Hoyland districts.

The Flockton Thin and Thick coals can also be readily recognized throughout the present area. Above the Flockton Thick, the Tankersley or Mussel Shell Ironstone is invariably present.

Higher measures are only represented in the extreme north-eastern corner of the present one-inch map and call for no special comment here.

South of the Dearne valley only very small outliers of Middle Coal Measures were shown on the original map, but exploitation of several seams during the intervening sixty years has enabled us to extend the area considerably. On Pool Hill, the highest ground between Bagden Hall and Nether End, a coal immediately underlies the sandstone which caps the hill. This coal is in three beds separated by dirt partings, and this character, together with its sandstone roof, led to its identification with the Whinmoor Coal (p. 83). Partly in consequence of this Pool Hill was shown on the map as surrounded by a triangle of faults. Green accepted this identification with considerable reserve, and of one of the faults he remarks:—"It is not altogether unlikely that such a fault exists, but the evidence is far from conclusive."[2] Subsequent workings have enabled us to recognize the Wheatley Lime Coal with its overlying *Carbonicola* band on the north flank of Pool Hill, and the Silkstone Coal below it is now being worked at Exley Gate Colliery, situated just east of the road to Bagden Hall where the line of section engraved on the map crosses it. We, therefore, regard the coal at the top of Pool Hill as the Swilley or New Hards, the faults on the north-west and the east sides being omitted. In the south part of this area we have a complete succession from the Silkstone Coal to the rock overlying the New Hards Coal; east of Wheatley Hill the Green Lane and Parkgate coals are present, but the exact relationship to the lower beds is somewhat obscured by a series of faults.

Details

The Silkstone or Blocking Coal.—To the north of Royd House this seam known as the Blocking Coal has been mined at Thorncliffe and averages two feet in thickness. When traced south of here, however, the

[1] Green, A. H., *op. cit.*, pp. 273, 274.
[2] *Op. cit.*, p. 575.

seam rapidly changes its character and becomes unworkable in the neighbourhood of Clayton West. At Wool Row, four hundred yards south of Royd House the Blocking Coal has been worked both along the outcrop and by mining. In this district the seam runs as follows :—top coal, 6 in.; dirt, 9 in.; bottom coal, 3½ in. Between here and Clayton West it does not appear to have been worth working. At Park Mill Collieries, Clayton West, it was met with at a depth of 204 ft. and was only four inches thick. It was here overlain by a band of grey rock 4 ft. 6 in. thick.

To the south of Park Mill Collieries it crops out in the village of Clayton West, and was seen in excavations close to Riding Wood Lodge, 900 yards south of Clayton West Church. It was here only a few inches thick, and of a very shaly nature. From thence its outcrop can be traced past Wheatley Hill to Bagden Wood, though it is much interrupted by important north-west—south-east faults. Traces of the coal are visible in stream sections in Bagden Wood and in Deffer Wood south of Wheatley Hill. At Exley Gate Colliery the seam is again workable; a sloping shaft has been driven to it and the coal proved to be 1 ft. 10 in. thick, but at the time of the re-survey in 1928 the pit had only been opened a short time and the workings were not extensive.

The Falhouse Rock.—In the measures above the Blocking Coal between Royd House and Emley Park there occurs a shaly and flaggy sandstone which corresponds to the Falhouse Rock of the Whitley and Grange Moor districts.[1] It is unrepresented on the south side of the Dearne valley. In the Emley Moor district it is in two beds separated by sandy shale, its total thickness being about 36 ft. Between Royd House and Emley Park it is overlain by a thin coal seam. At Exley Gate and to the north-east no sandstone is traceable, but on the south side of the ridge it appears to come in again in Deffer Wood and can be followed south-eastwards to Cannon Hall.

The Wheatley Lime Coal.—The Wheatley Lime Coal occurs 120 ft. above the Blocking or Silkstone Seam in the north, but south of the Dearne valley only about 60 ft. of shale intervenes. It maintains its character fairly constantly throughout the present area, though it is always a second-class coal and inferior to the New Hards Seam which occurs in the overlying measures. In the measures overlying the Wheatley Lime there is almost invariably a band full of *Carbonicola* casts and impressions.

The seam crops out round the hamlet of Royd House and from thence can be traced across Emley Park practically to Park Mill Collieries. The seam averages 2 ft. 7 in. in thickness but contains thin dirt partings. The following is a detailed section of the seam at Emley Moor :—

	Ft.	In.
Tops ' coal	1	0
Parting of shale...	0	0⅛
Good coal	1	7
' Hard ' coal	0	4
Dirt parting	0	0⅛
' Baring ' coal or ' bottoms '	0	2

A strong flaggy sandstone overlies the Wheatley Lime Coal at Royd House, and it can be followed eastwards gradually diminishing in thickness and dying out altogether near Park Mill Collieries. The seam was exposed in a road-cutting at Taylor Hill, Emley, 1,250 yards north of Skelmanthorpe railway station, and here the section was :—

	Ft.	In.
Flaggy sandstone	—	—
' Tops ' coal	0	3
Dirt parting	0	10
' Bottoms ' coal...	1	3

[1] ' Geology of the Country around Huddersfield and Halifax ' (*Mem. Geol. Surv.*), 1930, p. 103.

The Wheatley Lime has been extensively mined at Park Mill Collieries and the following is the average section of the seam :—

	Ft.	In.
Bind	—	—
Clod	0	9
Coal	2	8
Inferior coal	0	3

On the south side of the Dearne valley the seam has been called the Clayton Common Coal, and confused with the Blocking or Silkstone Seam (see page 108). It has been worked along the outcrop to the south and south-east of Wheatley Hill, and averages 2 ft. 3 in. in thickness.

An old shaft at Deffer Nook, about three furlongs south of Wheatley Hill, reached the coal at a depth of 54 ft.; the section was coal, 1 ft. 10 in.; dirt, 9 in.; coal, 9 in. At Upper Bagden at the junction of the roads to Lower Denby and Nether End the bottom coal was 2 ft. 3 in. to 2 ft. 7 in., the middle dirt parting 7 to 8 in. and the top coal 2 ft. 3 in. The *Carbonicola* band was said to be about 5 ft. above it; many specimens were collected from the tips, which have since then been removed.

The New Hards Coal.—About fifty feet above the Wheatley Lime Seam comes the New Hards Coal which has been extensively mined in the Emley, Park Mill and Clayton West districts. Around Emley Moor it constitutes a good class coal and averages 2 ft. to 2 ft. 6 in. in thickness. There is a dirt parting up to 2 ft. 6 in. thick in the middle of the seam. The New Hards Coal crops out on the southern slopes of High Chambers and to the north-east of Royd House, and the seam was well exposed during the recent re-survey of the district in a gully near Low House, Emley Park. The actual place is 150 yards west of Low House and about a mile north-east of Skelmanthorpe railway station. Here the following section was measured :—

		Ft.	In.
	Flaggy and shaly rag dipping 5°E.N.E. ...	—	—
	Fine black shale	5	0
New Hards Coal	Coal	1	6
	Dirt	1	0
	Coal	1	0
	Fireclay	2	0

The New Hards Coal has been extensively mined at Park Mill Collieries, and the following is the average section of the seam :—

	Ft.	In.
Blue bind	—	—
'Tops' coal	2	0
Dirt parting	1	2
'Bottoms' coal	1	0

On the southern slopes of the Dearne valley the New Hards crops out on Upper Common to the east of Wheatley Hill. Hereabouts it ranges from 2 ft. to 2 ft. 3 in. in thickness.

South of Wheatley Hill there are three outliers of this coal on hills capped by the sandstone immediately above it; these are Deffer Hill at the northern end of Deffer Wood, Trister Hill, a quarter of a mile to the east, and Pool Hill; their positions are shown on the one-inch map by the 700-ft. contour. At Deffer Hill almost all the coal has been wrought from the crop, but its position beneath the sandstone can be seen and there are large tips; at Trister Hill the crop-workings are completely grassed over, but can be traced in the fields on either side of the road. Pool Hill is the largest of the outliers, but the coal has all been gotten and the plan of the abandoned mine is dated 1877; the following is the section of the coal :—

	Ft.	In.
Inferior coal	0	3½
Dirt	0	5¾
Coal	1	4
Dirt	0	1¼
Coal	0	4

The dip was 1 in 7 about 25° east of south.

The overlying sandstone has been quarried beside the road to a depth of 20 ft.; it is current bedded and contains iron concretions; an air-shaft to the coal in the centre of the hill was 54 ft. deep, apparently all in sandstone.

The Green Lane Coal.—About 72 ft. above the New Hards Seam comes the Green Lane Coal which appears to be a thin but persistent seam in this district. Its outcrop can be fairly readily traced from the west of Moor Head to High Chambers, Emley Moor. Hereabouts its position is shifted by faulting, but to the east its line of outcrop runs from near New Speedwell Pit to Emley Old Hall. In this district it averages 14 in. in thickness. Three hundred yards east of Emley Old Hall is the important Thorncliffe—Park Mill Fault with a downthrow of 180 ft. to the east, which brings in much higher measures.

On the south side of the Dearne valley the Green Lane Coal crops out on the northern slopes of Swallow Hill, about 1,200 yards south of Clayton West Church. It is here about 13 in. thick, and was referred to by Green as the 'Scale Coal' and tentatively correlated with the Thorncliffe Seam of South Yorkshire.[1] It is, however, clear from its relative position in the sequence that it represents the Green Lane Seam of the Emley, Flockton and Grange Moor districts.

The Lepton Edge Rock.—Between the Green Lane Coal and the Parkgate Seam there are about seventy feet of measures which sometimes include a thin unimportant coal seam, and occasionally a very variable flaggy sandstone known as the Lepton Edge Rock. This sandstone gives rise to a prominent feature along the western slopes of Emley Moor to the west of Moor Head, but it dies away eastward and is unrepresented at Emley Old Hall. The Lepton Edge Rock also forms a well-marked feature on the southern slopes of the Dearne valley at Swallow Hill, one mile to the south of Clayton West.

The Parkgate Coal.—The Parkgate Coal crops out in the low ground to the south of Warburton and Hag Hill, Emley, and can be traced thence past Hallas Cottages to Owlers Wood, 300 yards north of Emley Old Hall. In this district the coal averages about two feet in thickness. On the southern side of the Dearne valley the same seam has been mined near Wheatley Hill and to the south of Clayton West. In this district the continuity of the outcrop is interrupted by several north-west and south-east faults. During the re-survey of the present area it was being worked along the outcrop at Toppit farmstead, 600 yards south-east of Wheatley Hill. The section of the seam here was as follows :—

	Ft.	In.
Tops. Good coal	2	0
Bind	5	0
Drub. Poor shaly coal	0	6
Bottoms. Good coal	2	6

In the measures above the Parkgate Coal a sandstone occurs in the Wheatley Hill district which occasionally gives rise to prominent features.

The Flockton Thin Coal.—The Flockton Thin Coal crops out along the southern slopes of Hag Hill and Warburton to the south of Emley, and has been worked in the past. The seam is here fifteen inches thick and is overlain by about ten feet of shale, above which comes the Emley Rock.

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 281.

The Emley Rock.—The Emley Rock gives rise to a well-marked feature at Warburton and Hag Hill. There is a small disused quarry in this rock at Warburton where it is seen to consist of thinly laminated flaggy sandstone or rag. The Emley Rock is not more than 25 ft. thick in this district.

The Flockton Thick Coal.—The Flockton Thick Coal occurs about 54 ft. above the Flockton Thin Seam in this district, and reaches up to 3 ft. 6 in. in thickness. It covers a very small area about 250 yards north-east of Park Mill Collieries, Clayton West.

The measures above the Flockton Coals.—The measures above the Flockton coals occupy a very small area shown along the north-eastern margin of the one-inch map, and call for little comment here. They include the Tankersley Ironstone, Joan Coal, Thornhill Rock and associated measures. They occur in a small faulted belt to the north of Park Mill Collieries, and 400 yards east of Emley Old Hall. The Tankersley Ironstone was worked along the outcrop to the south-east of Emley in mediæval times, and has not been tried since; it is apparently highly calcareous owing to the remarkable abundance of *Carbonicola* shell in it.

The Joan Coal is thin and relatively unimportant. The Thornhill Rock forms a small patch of elevated ground to the east of Emley.

CHAPTER V

GEOLOGICAL STRUCTURE

Folding

That part of the Pennine Range which is represented on the map is structurally the result of two dominant folds, the Pennine Anticline with its closely related folds along the western edge of the area, and the Alport Dome, the most northerly manifestation of the gentle folding of the Derbyshire Dome to the south, which influences the southern part of our area.

Between these two major structures the beds, apart from minor oscillations, dip generally at low angles to the north-east, with a tendency in the north of the area to swing round to the east. The accompanying sketch-map (Fig. 13, p. 117) illustrates the disposition of these folds and the inclination of the strata.

The significance of the two structures we have indicated is readily apparent when the Pennine folding in neighbouring areas is considered (Fig. 12). To the north, from the confines of our area to Boulsworth Hill east of Burnley the Pennine uplift consists of one north-and-south monocline with a steep westerly limb. This is the 'Pennine Anticline.'[1] Parallel subsidiary disturbances are present, but unimportant. To the south the dominant structure is the Derbyshire Dome, a gentle pericline of wide amplitude, which brings up the Carboniferous Limestone to form a wide upland area.[2] Between it and the Cheshire Basin is a zone of sharp north-and-south subsidiary folds involving the Millstone Grits and Coal Measures.[3] They are the direct southward continuations of the Pennine and Mossley disturbances. Thus our area is one of transition between the simple monoclinal folding of the north and the more complex folding of Derbyshire; within the confines of the map the Pennine Anticline begins to be shouldered to one side, as it were, by the powerful Derbyshire Dome, until farther south its representative occupies a relatively unimportant position on the margin of this structure.

The Pennine and Mossley anticlines form the eastern boundary of the South Lancashire Coalfield, cutting it off abruptly from the lofty Millstone Grit moors of the Pennines. They lack the simplicity of the monoclinal fold of the country to the north, in that they are sharp folds of small amplitude intimately connected with

[1] 'Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, pp. 118-120.

[2] Bemrose, H. H. Arnold, 'Lower Carboniferous Rocks of Derbyshire,' *Proc. Geol. Assoc.*, vol. xvi, 1899, p. 170.

[3] 'Geology of North Derbyshire' (*Mem. Geol. Surv.*), 1887, pp. 12-17.

intense faulting. When looked at broadly they are seen to constitute the axial zone of a large markedly asymmetric wrinkle characterized by the steep dips of the South Lancashire Coalfield to the west and the gentle opposite inclination of the Millstone Grit plateau to the east.

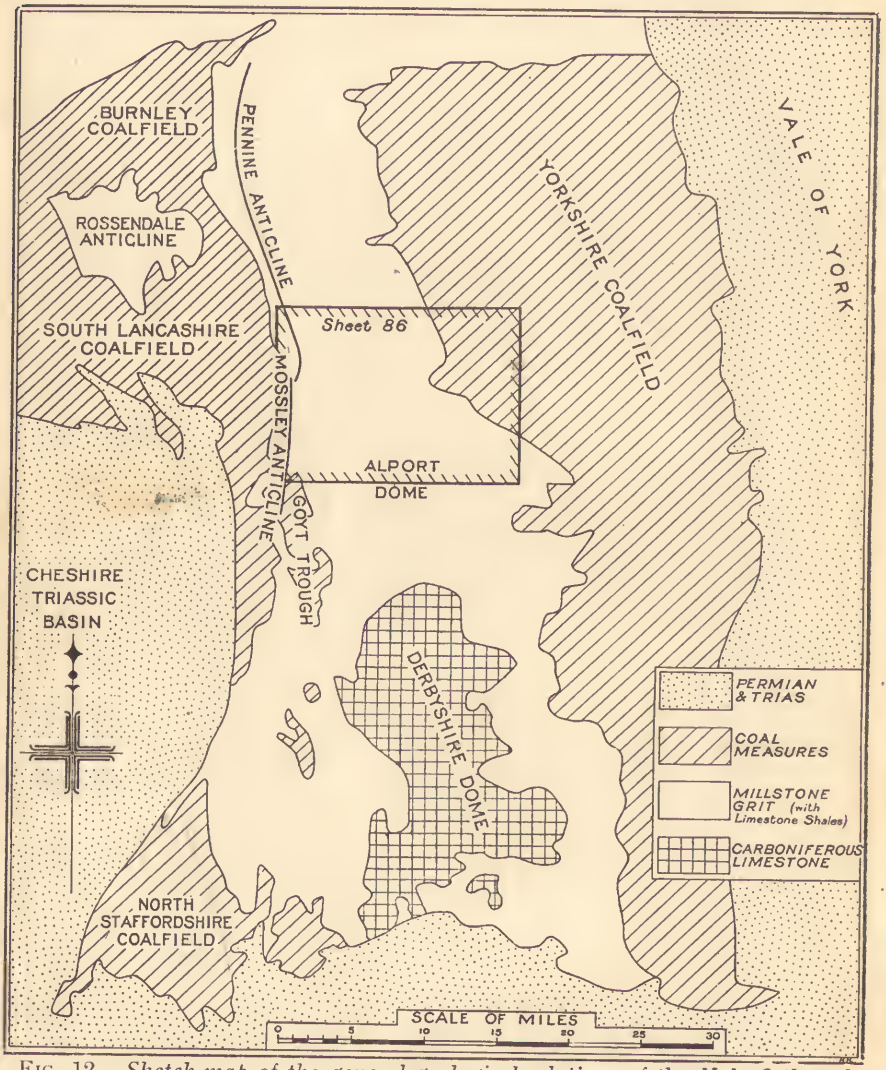

FIG. 12.—*Sketch-map of the general geological relations of the Holmfirth and Glossop area.*

The most important element in the accompanying faulting is the Tame Fault,[1] a great fracture with a westerly downthrow which runs from north to south more or less along the Tame valley.

[1] The local names Tame Fault and Mossley anticline are introduced with some diffidence, for both these structures continue southwards into ground which has not been worked out in detail.

In the following pages the Pennine and Mossley anticlines and the Tame Fault are each described separately, as far as is possible.

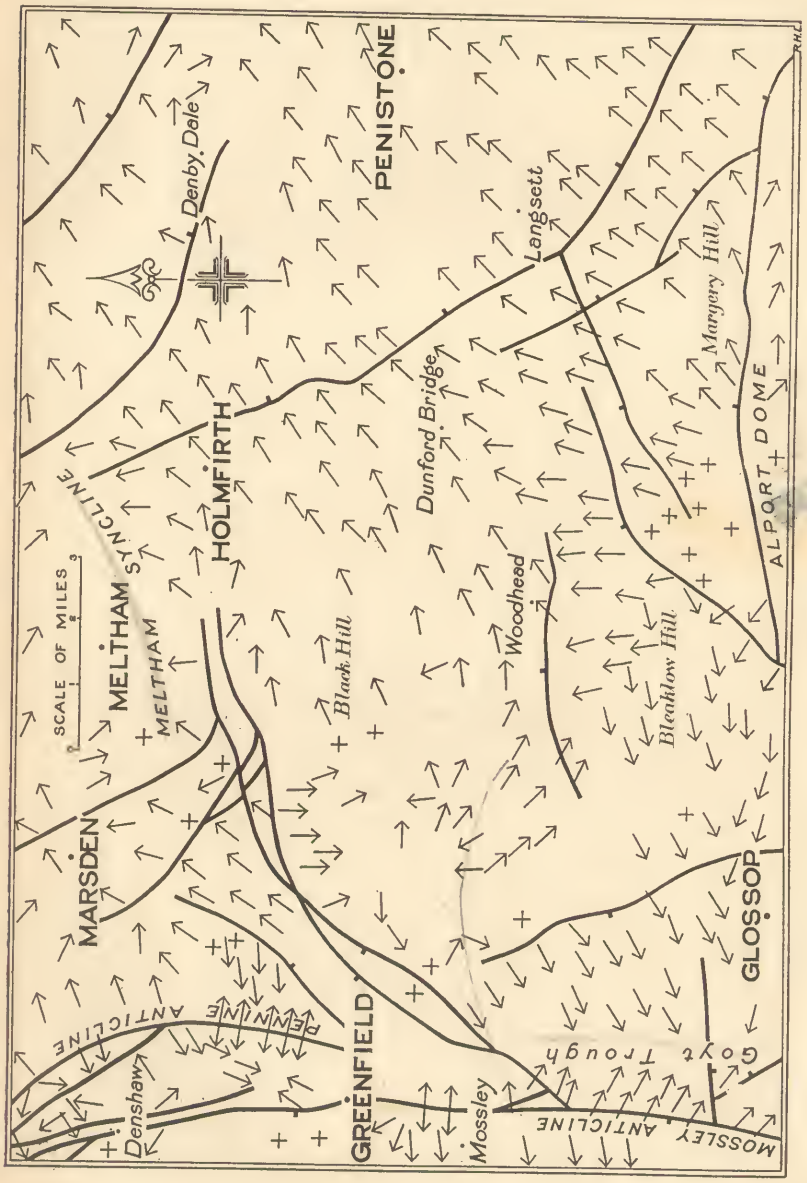

FIG. 13.—*Map of the principal folds and dips.*

The Pennine Anticline.—As this structure approaches our area from the north its plain monoclinal form begins to be disturbed by the appearance of subsidiary folds and of extensive faulting.[1] The main anticlinal axis enters the area we are

[1] 'The Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 120.

describing at Millstone Moss, north of Denshaw, whence it runs in a south-south-easterly direction into the Saddleworth valley.

In the Readycon Dean district (see Fig. 6, p. 28) the Kinderscout Grit and overlying beds dip away to east and west from the anticlinal axis, but rapidly flatten out eastwards, being practically horizonal on Buckstones Moor. There is a fault along the axis here, but its throw cannot be large. It is identical with the 'Anticlinal Fault' of Hull,[1] and although of less importance to the north than Hull supposed, it is here beginning to increase. At Ragclose Edge a section is exposed along the axis of the fold. The massive basement beds of the Kinderscout Grit completely surround an inlier of Grindslow Shales and dip away in all directions, indicating a dome-shaped structure, the eastern limb of which is somewhat complicated by the anticlinal fault.

South of Castleshaw Moor the local northerly pitch brings up beds below the Kinderscout Grit, and from here to Greenfield the axis is coincident with the narrow outcrop of Shale Grit which ranges along the Saddleworth valley in a southerly direction. The beds dip off the flanks of the anticline at 10 to 40 degrees, but wherever there are exposures along or near the axis the rocks are seen to be dipping steeply, vertical, or faulted and contorted. For example, the Shale Grit in the railway-cutting 500 yards south of Diggle Station is dipping west at 50 to over 70 degrees, the axis being close by. At the station itself the beds on the other side of the axis are dipping east at about 40 degrees.

The fault along the axis is joined near Diggle by the Castleshaw Faults which cross the moors around Readycon Dean from the north-west. It was originally mapped and described by Hull as part of the 'Anticlinal' or 'Great Pennine Fault.'[2] It is not certain that it is here the only fault, or that it is continuous as far south as shown on our maps. Near Upper Mill it probably has a large westerly downthrow.

Exposures south of Saddleworth are poor owing to a covering of drift, but the anticline can be traced nearly to Greenfield. It bends slightly to the west and dies out near Waterside, the Kinderscout Grit in the moorland to the south showing no trace of its continuation. Nor can the fault along its axis be traced beyond, or indeed as far as Waterside. In this respect our account differs from that of Hull, who described the 'Great Pennine Fault' as continuing southwards to join near Greenfield what we have called the Tame Fault.[3] We can find no evidence of continuity between either the two faults or the Pennine and Mossley anticlines.

The Tame Fault.—This can first be recognized in the west of the Readycon Dean district, where a great fault is seen ranging almost north-and-south on the west side of Tups Head and Rough Hey Moss, bringing up the Kinderscout Grit of those places

[1] Hull, E., 'Geology of the Burnley Coalfield' (*Mem. Geol. Surv.*), 1875, pp. 88, 89.
[2] *Ibid.*, also 'Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, Frontispiece and p. 9.
[3] *Ibid.*, p. 57.

against the Middle Grits on the west. There is a faulted anticline just east of and roughly parallel with this fault, for the Kinderscout Grit disappears in that direction beneath the Middle Grits of Lurden. The east side of this anticline is cut away by faulting, but the axis corresponds closely with the line of Crook Gate Reservoir. Although so much broken by faults as to render local dips extremely variable, the Middle Grit area around Lurden is seen to represent the complementary syncline between this anticline and the Pennine Anticline to the east.

The fault at Denshaw is approached by a nearly parallel fault on the west, which has arisen by the running together of some of the many north-westerly faults farther north. These two faults now run close together southwards towards Delph, between them throwing down Middle Grits on the west against Shale Grit on the east. The anticline through Crook Gate Reservoir appears to have converged southwards on these faults, for north of Delph while the Middle Grits dip gently westwards away from them the Shale Grit on the other side dips eastwards at 10 to 40 degrees; the intervening ground between here and the Pennine Anticline about a mile and a half to the east is folded into a gentle syncline with a north-west and south-east axis, in which is preserved the strip of Kinderscout Grit between Bleak Hey Nook and Dob Cross.

South of Delph the eastern branch of the fault dies out against a cross-fault, and the western branch continues to Greenfield with a throw of about 1,250 feet, Rough Rock and Coal Measures being brought down on the west against Kinderscout Grit on the east. Away from the actual fracture the beds are dipping so gently that the anticlinal structure can barely be recognized along this part of the fault. The rocks close to it are seen in various places to be broken and dipping at high angles, but unfortunately no actual section of the fault can be seen.

At Greenfield the anticlinal structure, hitherto indicated in a partial and uncertain manner, and in places almost absent, suddenly becomes dominant, while the throw of the fault decreases, so that from here to the southern boundary of the area we have a sharp anticline with the Tame Fault running pratically along its axis.

The Mossley Anticline.—The recognition that this structure is independent of the Pennine Anticline has necessitated the introduction of a new name. As we have seen, it suddenly appears as a well-marked anticline near Greenfield, less than a mile west of the southern end of the Pennine Anticline. It can be followed from Greenfield to the south-east corner of the area, where it enters drift-covered ground. It has a slight southward pitch, so that higher beds occupy the crest in the south than in the north. On the east of the anticline the eastward dips die out within a distance of from half a mile in the north to two miles in the south; farther east is a wide expanse of moorland where the rocks are

gently folded but considerably faulted. On the west side, however, high westerly dips persist for a considerable distance from the crest, the whole of the beds up to the base of the Middle Coal Measures cropping out within a distance of two miles.[1]

The structure of the anticline in the Mossley district is shown by Section B, Fig. 14. Here the rapid flattening out of the eastern limb is plain. For about 5 miles farther east from Buckton Moor the general dip continues to be slight, but then gradually increases and assumes a north-easterly direction, so that Coal Measures first appear about 14 miles from the anticlinal crest on this side.

The great disturbance made by the faulting along the axis near Mossley can be seen more or less distinctly in Castle Clough, nearly a mile south-east of the Station. Here the main fault is in two branches close together, with a smaller offshoot on the west gradually diverging northwards. It is not possible to say which way these faults hade (Fig. 14, Section B). Between Castle Clough and Harrop Edge there are no exposures in the neighbourhood of the anticlinal axis, but the fault can be traced with fair accuracy. It still has a large downthrow westwards, and appears to run along the crest of the fold. Section A, Fig. 14, shows the folding west of Hollingworth Hall to be fairly simple, but the approach to symmetry is more apparent than real, for whereas the eastern limb flattens out just beyond the edge of the section the western limb does not do so, and a great thickness of Lower Coal Measures is brought in farther west with even steeper dips than are shown on the section. The faulting does not appear to disturb the inclination of the beds in the section, but the rocks are so poorly exposed that there is no evidence of dips, steep or otherwise, close to the fault. It is likely that the beds dip away steeply from the fault on the east side at least, since at Harrop Edge, where the Kinderscout Grit is brought against the fault, the dips are high, up to 75 degrees or more.[2] Here large quarries in the lower beds of Kinderscout Grit provide remarkable sections, showing the steeply-dipping grits shattered, with mudstone partings smashed and contorted. A small exposure close to the fault shows grit standing vertically, with some of the silica recrystallized.

The Alport Dome.—Along the southern edge of the area shown on the map the Shale Grit is brought up by a broad gentle uplift to form the high moors south of Bleaklow Hill. There is an area of approximate horizontality east of that hill, and on Alport Moor farther south. From this area the dips radiate in general to west, north and north-east. The change in direction from west to north is abrupt, and from north to north-east extremely gradual. The dips seldom exceed 10 degrees.

[1] 'Geology of Manchester and the South-East Lancashire Coalfield' (*Mem. Geol. Surv.*), 1931, p. 168 and Map, Sheet 85.

[2] 'Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 58, fig. 14.

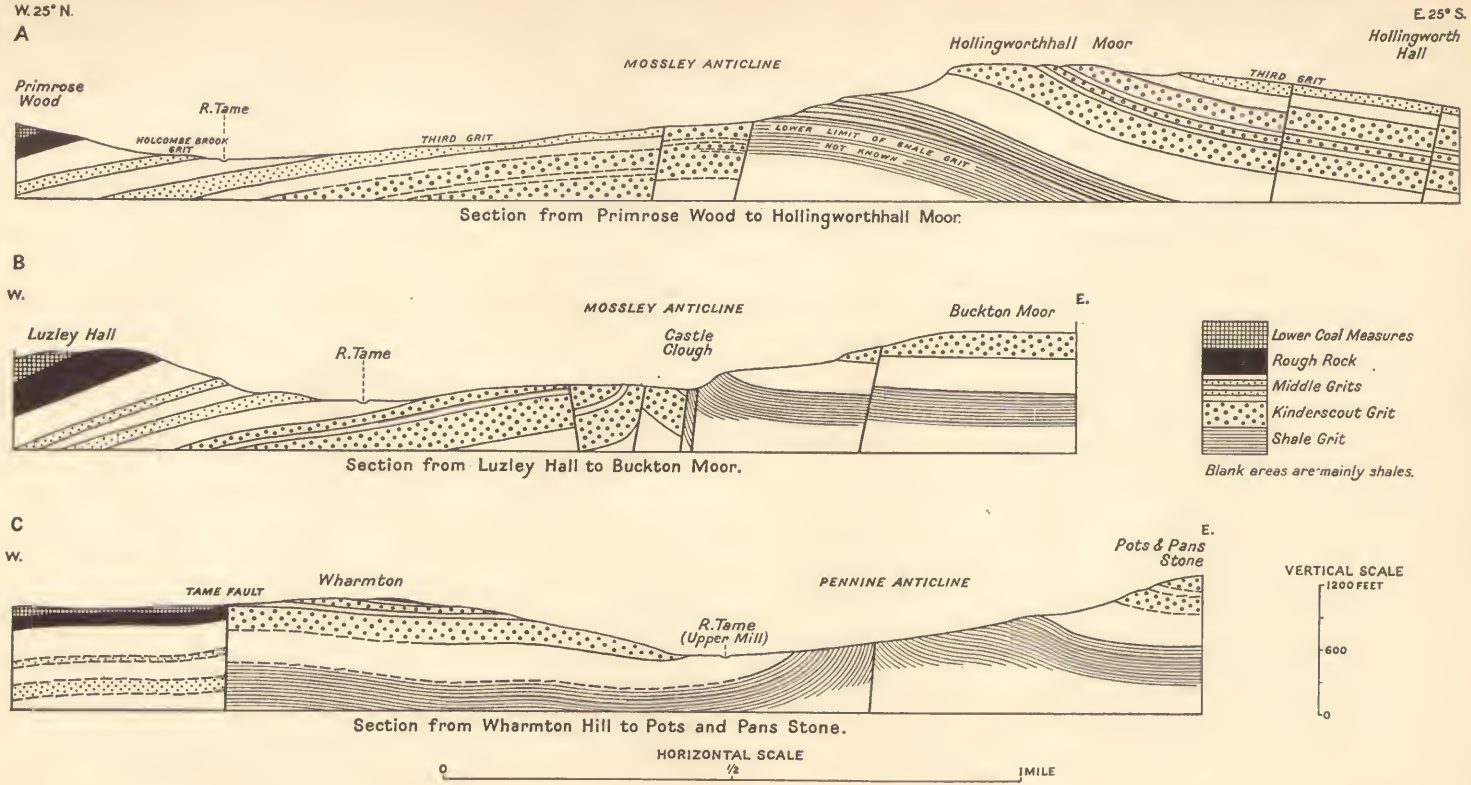

FIG. 14.—*Sections across the Mossley and Pennine Anticlines.*

We can only give a partial description of this structure, for the south side of it is beyond our field. The Old Series one-inch map (Sheet 81 N.E.) shows southerly dips along the Ashop valley between Alport Moor and Kinder Scout, which plateau would appear to occupy a gentle syncline.

The influence of the Alport Dome may, however, be traced for a considerable distance to the north (see Fig. 13, p. 117). The sudden widening of the Millstone Grit outcrop south of Holmfirth, plainly visible on the geological map, is due to this influence.

The Alport Dome is the most northerly manifestation of the gentle folding of wide amplitude of the Derbyshire Dome. In view of the evidence for minor folding in the Kinderscout and Edale districts,[1] not yet fully worked out, it seems expedient for the present to use a local name, which could be dropped if necessary after further research.

The Goyt Trough.—Between the Mossley Anticline and the Alport Dome, and much closer to the former than to the latter, lies a shallow but well-defined syncline. It appears to commence close to the Harridge-Bradshaw fractures at Cowbury Dale, and runs almost south through Hollingworth. Farther south it increases in magnitude and has long been known as the Goyt Trough.[2] The Coal Measures south of Mottram are brought in, partly by faulting, along this syncline. In the Glossop district it acts as the complementary syncline between the uplifts of Mossley and Alport.

Minor Folds.—In the area east and north-east of the major folds the general north-easterly dip is complicated by certain fluctuations, apparent on the sketch-map (Fig. 13, p. 117). The discordant dips seen in the first 5 miles east and north-east of Greenfield appear to indicate tilting of blocks between faults rather than actual folding; in all cases the dips are low. The plateau west of Black Hill, between the Crowden Fault and the Harridge-Bradshaw fractures, shows no definite structure other than this apparent gentle tilting of blocks. It does not participate in the general north-easterly dip, and may perhaps be connected with the anticlinal folding of the Derbyshire Dome. On its south side there is a suggestion of synclinal structure along the Crowden Fault, on its east side the north-easterly dip commences, and on its north side lies the Meltham syncline.

The Meltham Syncline.—Although on the whole the beds have a fairly uniform dip over the north-western part of the sheet, a broad shallow synclinal passes through Meltham, its axis corresponding closely with the valley of the Brow Grains Beck or Meltham Brook. It trends in an east-north-easterly direction, and can be followed over a distance of about five miles from Deer

[1] See, in addition to Old Series one-inch Sheet 81 N.E., J. W. Jackson, *Journ. Manch. Geol. Assoc.*, vol. i, pt. i, 1927, pp. 15-32; and W. G. Fearnsides 'The Geology of the Eastern part of the the Peak District,' *Proc. Geol. Assoc.*, vol. xliii, 1932, p. 174 and Plate viii.

[2] 'Geology of North Derbyshire' (*Mem. Geol. Surv.*), 1887, p. 13 *et seq.*; also 'Geology of the country around Stockport, Macclesfield, Congleton and Leek' (*Mem. Geol. Surv.*), 1886, Frontispiece and p. 43.

Hill Moor to Honley in the east. This slight flexure produces a marked effect on the landscape : the outlier of Rough Rock capping Deer Hill Moor to the west of Meltham is bent up both north and south to form the craggy scarps of Shooters Nab and West Nab (Fig. 7). In a similar manner the Huddersfield White Rock forms a prominent scarp at Meltham Edge overlooking the Colne valley, and thence the rock dips rapidly south towards the village of Meltham. South of that village the White Rock has a persistent northerly dip and forms a prominent scarp feature at Banister and Royd Edges.

Other local flexures of no importance are found, such as the syncline at Torside Castle (p. 40). Local disturbances connected with the large faults are common, and often display folding of some intensity.

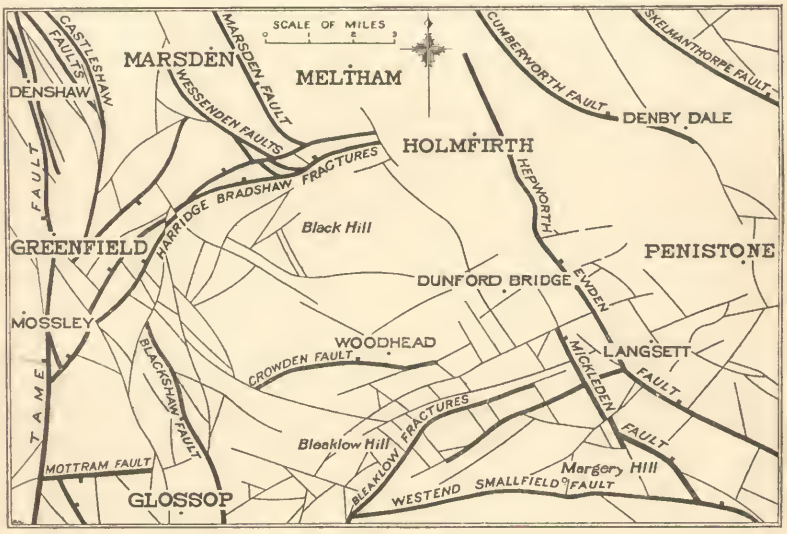

Fig. 15.—*Map of the principal faults.*

Faults

The faults along the line of the Pennine uplift, described above, have a predominant north-and-south trend; those over the remainder of the area may be broadly referred to two main systems. One set trend approximately north-east and south-west while the remainder largely follow a north-west and south-east direction, or approximately at right angles to the former. Several faults, however, diverge considerably from these two directions, a common tendency being to follow a more nearly east-and-west direction; three of the more prominent faults in fact run practically east-and-west. On the other hand, both the north-easterly and the north-westerly groups show a tendency to swing round towards a north-and-south direction as they approach the main Pennine disturbance. In the following description the names adopted for convenience are those used on the accompanying map (Fig. 15).

The Dick Hill Fault has a downthrow to the south-east of over 200 ft. near the Pots and Pans Stone, but it appears to decrease towards the south.

The Harridge-Bradshaw Fractures make great breaks in the Kinderscout Grit escarpments at Harridge and in the Greenfield Brook valley. South of the Pots and Pans Stone the northerly fracture brings the Kinderscout Grit down against the Shale Grit. The faults converge near Raven Stones and cross Greenfield Brook in a greatly disturbed area; they diverge farther east and bring in a trough of Middle Grit near Wessenden Head.

The Wessenden Fault consists of three or more parallel steps close together, with a large north-easterly downthrow. They cut off the lower beds of Kinderscout Grit along the south-west side of the Wessenden valley, forming a strong fault-scarp. The intense crushing of the grit by these faults can be observed in the small streams running into this side of the Wessenden valley.

The Marsden Fault throws the Rough Rock outlier of West Nab against the Middle Grits, and, like the Wessenden Fault, dies out against the Harridge-Bradshaw fractures.

The Greenfield-Glossop Fault changes its throw between White Gate and North Britain. It is nowhere a big fault, but for some distance it forms the western edge of the Kinderscout Grit area north of Glossop.

The Blackshaw Fault has a large westerly downthrow, and truncates in a striking manner the high Kinderscout Grit moors on both sides of the Etherow. The belt of smashed grit along its course can be seen in Arnfield Brook. At Blackshaw it makes a strong fault-scarp.

The Mottram Fault and the Crowden Fault are two of the three large faults in the area which run nearly east-and-west. The former has a great downthrow to the south; it forms the northern boundary of the Coal Measures basin at Mottram, bringing these beds against the Kinderscout and Pule Hill Grits on the north. The latter throws down to the north, and its effect may be seen by comparing the levels of the Kinderscout Grit base on the north and south sides of the valley. Its throw at Crowden Church must approach 300 ft.

The Bleaklow Fractures.—The moors south of Woodhead and Dunford Bridge are traversed by a number of roughly parallel south-westerly faults, which on the south-west break up into the complex system of faults on Shelf Moor, and on the north-east die out against the Mickleden and Hepworth-Ewden faults. Trending almost at right-angles to them are several short north-westerly faults, which in nearly all cases die out against the south-westerly ones. The two sets of faults thus divide the area into many small rectangular blocks; none of these blocks appear to have been

tilted by the faults, for discordant dips are conspicuously absent. The two largest faults run on opposite sides of Barrow Stones, and throw down to the north. The maximum throw of the southerly one is over 300 ft. at Round Hill. The northerly one has a smaller throw, but its effect on the scenery is more spectacular, for its course west of Howden Edge is marked by a series of great shifts in the level of the Kinderscout Grit base. The narrowness of the Kinderscout Grit outcrop between Swains Head and Howden Edge is due to the northerly throws of these two faults and of the lesser parallel one on the north.

The Westend-Smallfield Fault begins in the disturbed area on Shelf Moor and runs almost due east. The shattered rocks along its course are well exposed in the Westend River and in the Derwent 400 yards south of Slippery Stones. Its throw is down to the north, but is not apparently great. It joins the Mickleden Fault near Smallfield.

The Mickleden Fault.—On Midhope and Broomhead moors this fault throws the Middle Grits down east against the Kinderscout Grit. Its most conspicuous effects are in Mickleden (see p. 43). It splits up on Broomhead Moor and continues down the Agden Valley as a trough-fault.

The Hepworth-Ewden Fault is first recognized about half a mile to the south of Honley. It has a downthrow to the east, which increases rapidly when traced southwards. It is well marked in the Lower Holme valley around Mytholm Bridge and Thongsbridge where the Rough Rock along the eastern side of the fault is brought against the Huddersfield White Rock and lower members of the Middle Grit Series.

The fault is well exposed in the railway-cutting just to the west of Thongsbridge Station, and again in Pickles Clough, Hepworth, where it has a downthrow of about 100 ft., bringing Soft Bed Flags on the east against Rough Rock on the west; the stream forms a waterfall in crossing it from the hard grit to the Coal Measures shales. Other exposures are in the valley of the Little Don and in Thickwoods Brook (p. 64), where the strata are greatly broken and contorted.

The Cumberworth Fault is a southerly continuation of the Longwood Fault in the Huddersfield district.[1] It can be followed in a north-west to south-east direction from Hey Wood past Thurstonland and Fulstone towards Cumberworth. Throughout this area its throw north-eastwards does not anywhere exceed 100 ft. At Denby Dale, however, it increases to 150 ft., but after crossing the railway the fault splits up and dies out among a number of small faults east of Ingbirchworth.

The faults between this and the Skelmanthorpe Fault are not in themselves of great importance, but are noteworthy as bringing in the patch of Middle Coal Measures around Pool Hill (p. 112).

[1] 'Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 125.

The Skelmanthorpe Fault is the south-easterly continuation of a group of faults in the Coal Measures in the Lepton district. Near Royd House it brings the Middle Coal Measures alongside measures with the Beeston Coals. Its course hereabouts has been accurately delineated by means of numerous coal-workings. It runs in a south-easterly direction past Skelmanthorpe railway station, and can be followed as far as Scissett. On the southern side of the Dearne valley it splits up into several branches, the positions of which have been located in working the Whinmoor Coal.

The Age of the Earth-movements

The southern Pennine folding is generally regarded as being mainly the result of the Post-Carboniferous earth-movements, although slight folding took place much later. It is possible that the slight contemporary disturbances mentioned below indicate an early manifestation of these movements. In surrounding areas where strata of Permian and Triassic ages overlie the Carboniferous rocks, the faulting is chiefly pre-Permian, but partly post-Permian and partly post-Triassic. We may suppose the same to be true of this area.

The faulting appears to have taken place at about the same period as the folding. In the country immediately north of this area the main part of the faulting has been ascribed to torsional stresses set up by unequal or irregular uplifts along the line of the Pennines.[1] The faults which traverse most of the present area are of the same type, belonging to the system of interesting faults typical of the Yorkshire Coalfield.

There is no evidence that the faults with any one trend are earlier or later than the rest. Each set truncates or is truncated by faults of the other sets, and faults with different directions sometimes appear to flow into one another. Horizontal slickensides have been observed on many fault-planes, but horizontal movement does not appear to have been extensive.

The north-and-south faults along the Pennine and Mossley anticlines appear to be almost, if not quite, vertical, and some sections suggest that they are reversed; but their great vertical displacements do not well accord with this view. The origin of the faulting must be in some way connected with the folding, but the precise nature of this connection cannot be stated until progress of the re-survey allows a greater area to be taken into consideration.

Contemporary Movements

It has been pointed out above (p. 76) that the Lower Coal Measures thicken both north and south from the neighbourhood of Hepworth and Denby Dale. Moreover, a number of small changes in the sequence of measures appear to take place in approximately the same position, suggesting a line of contemporary disturbance. The subject is not of great practical

[1] 'Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 123.

importance within the area here described, but derives considerable interest from the fact that it appears to be an integral part of a phenomenon of the greatest importance in the Yorkshire Coalfield as a whole. The field has, for many years, been divided for economic purposes into two parts known respectively as West Yorkshire and South Yorkshire. The division is based on changes which affect nearly all the coal seams and range themselves along a definite line or belt, with which the boundary, with local exceptions, coincides. It is sufficient here to mention such well known instances as the passage from the Barnsley or the Silkstone seams of South Yorkshire to the Warren House and Blocking Beds of West Yorkshire.[1] The effects of this persistent disturbance can be traced in the present area; it is convenient to follow it from the country to the east, where it is well known, to the west, that is from the higher to the lower beds in the sequence.

Fig. 11 (p. 107) shows a number of sections along a line running north-west to south-east, or at right angles to the disturbance, through Clayton West; the Silkstone or Blocking Coal is seen to thin to a few inches and the Parkgate Coal passes to the Old Hards facies in the middle of the area, though the general sequence of measures is similar on either side. In the same district the Whinmoor Coal disappears abruptly near Nether End (p. 99), but comes in again a short distance to the south. The Better Bed and Black Bed coals, important seams in West Yorkshire, both die out near Kirkburton, and are not found south of the axis of disturbance (p. 81). No conspicuous changes in the character of the lower beds take place, but the thinning is remarkable: from the Rough Rock to the Greenmoor Rock at Jackson Bridge there is a loss of 200 ft. in three and a half miles from the north and of 250 ft. in seven miles from the south. As these measures have a narrow outcrop in the escarpment, the figures given above are practically direct measurements. Those given for the total thickness of the Lower Coal Measures (p. 76) are calculations, but show losses of 350 ft. and 520 ft. from north and south respectively. It is clear, therefore, that in the Lower Coal Measures the disturbance takes the form of an attenuation of the beds, but the minimum thickness may lie a short distance to the north of the datum line adopted here, that is the line of section engraved on the map.

Following this line farther west into the Millstone Grits we find that between Black Hill and Wessenden the beds between the Kinderscout Grit and the Huddersfield White Rock are unusually thin; individual beds, such as the Readycon Dean Series (p. 47) and the Beacon Hill Flags (p. 60), are locally absent or untraceable in some parts of the central area.

This thinning of the Millstone Grits and Lower Coal Measures is diagrammatically represented in Fig. 16. For convenience of reference we have introduced the name 'Holme Disturbance' for this feature. Conditions do not allow of its being traced below

[1] *Cf.* D. A. Wray, 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix vi, pp. 127-137.

the top of the Kinderscout Grit, but the facts just stated show that some movement was taking place contemporarily with the forma-

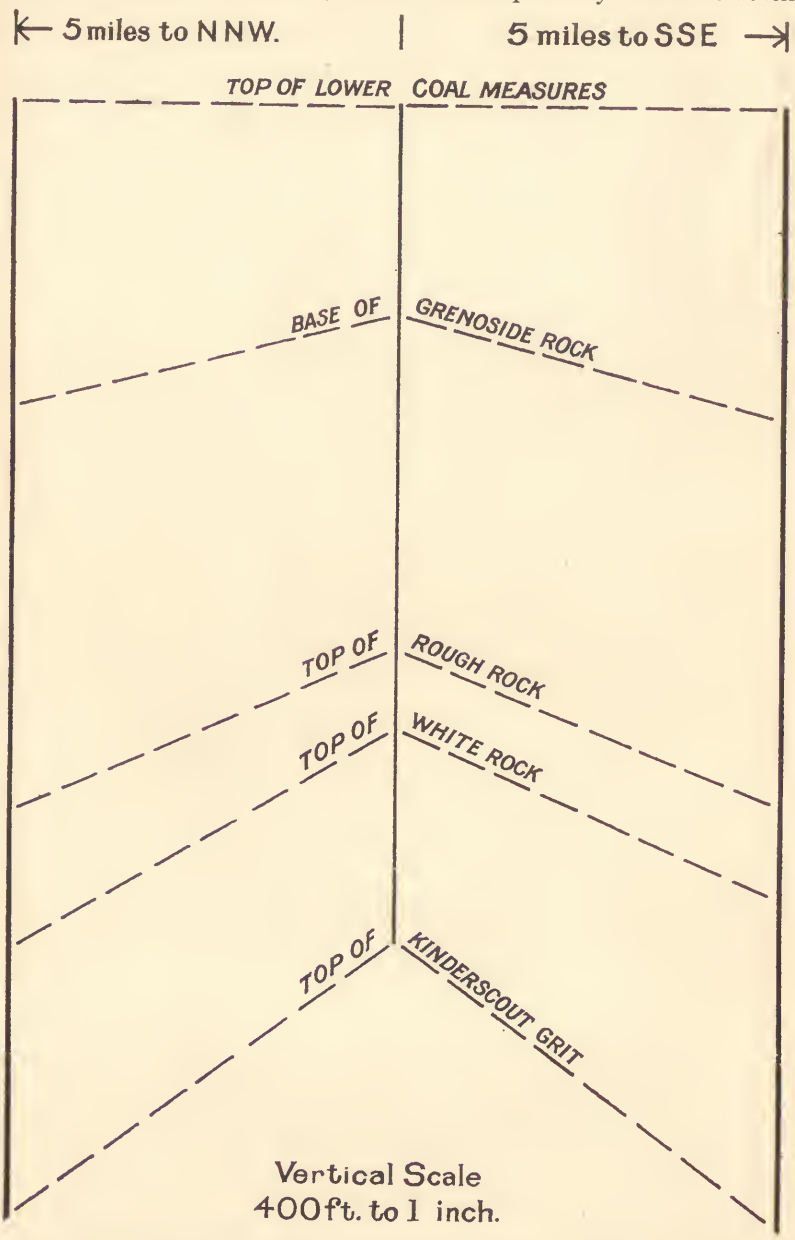

FIG. 16.—*Diagram of the thinning of the measures along the line of the Holme Disturbance.*

tion of the higher beds of the Millstone Grits and the Lower Coal Measures, and it seems probable that there is some connection with the changes in the character of the coal seams in the Middle

Coal Measures. Evidence is gradually accumulating, mainly as a result of the work of the various Coal Survey Committees, which suggests the existence of other somewhat similar belts of contemporary disturbance in the Coal Measures. These may be found to have originated in Millstone Grit times in the southern part of our area; but no definite statement can as yet be made.

Isostatic Compensation

Owing to the number of deep trenches that have been cut for the construction of reservoir dams, the area has afforded opportunity for the study of superficial movements confined to the beds of existing valleys; such movements are usually referred to ' isostatic compensation.' The trench for the Langsett Reservoir dam may be mentioned as an instance: this was cut for the most part in the shales below the Rough Rock, in which one of the goniatite bands was noticed. The shales showed a fairly uniform dip at a low angle to the north-east, except in the middle, or bottom of the valley, " where some curiously contorted beds were interpolated with bands of clayey or crushed material, but they disappeared at a depth of 100 ft. below the surface, and normal floors of shale came in."[1]

[1] Watts, W., ' Excursion to Langsett,' *Trans. Manchester Geol. Soc.*, vol. xxvi, 1901, pp. 263-268.

CHAPTER VI

GLACIAL AND RECENT DEPOSITS

Boulder Clay

Boulder-clay in the area defined by this sheet is confined to a narrow strip along the western edge. This distribution has been determined by the position of the main Pennine escarpment, which was reached but not passed by the North-Western ice-sheet during its advance across the Lancashire plain.

The history and nature of these deposits is, therefore, closely related to the sequence of events which took place along the ice-front both in this district and to the north and south of it. Thus it is practically impossible to give a connected account of the Glacial history of this small area without being able to refer to these related phenomena. Fortunately, Messrs. Jowett and Charlesworth in a recent paper[1] have worked out the Glacial history for an area extending from Blackstone Edge in the north to Derbyshire and Shropshire in the south; thus including the drift-covered area on this sheet.

In addition, the Survey Memoir for Sheet 85 (Manchester),[2] the Sheet adjacent to Sheet 86, contains an account of the Glacial deposits to the west of the present area.

Exposures of the boulder-clay are few, but where seen it is a tough reddish-brown to purplish-brown clay containing pebbles and boulders. These included erratics consist of Carboniferous rocks with a generous percentage of rocks from the Lake District and the Southern Uplands of Scotland: an assemblage which is typical of the North-Western Drift.

As this boulder-clay is traced up the slopes of the hills its character changes; the clay becomes sandier and the proportion of local rocks increases at the expense of the foreign until the latter become rare. This change has been alluded to by Dr. Jowett[3] who puts forward the explanation that the relatively clean upper layers of the ice-sheet were responsible for the collection and deposition of this local type of drift. The lower and more heavily charged layers were not forced sufficiently high up the slopes to affect the nature of the drift.

In a paper by R. Richardson[4] the following reference is made to the occurrence of shells in the drift:—" Arctic shells were also

[1] Jowett, A., and J. K. Charlesworth, 'The Glacial Geology of the Derbyshire Dome and the Western Slopes of the Southern Pennines,' *Quart. Journ. Geol. Soc.*, vol. lxxxv, 1929, pp. 307-334.

[2] 'The Geology of Manchester and the South-East Lancashire Coalfield' (*Mem. Geol. Surv.*), 1931, pp. 175-187.

[3] Jowett, A., 'The Glacial Geology of East Lancashire,' *Quart. Journ. Geol. Soc.*, vol. lxx, 1914, p. 213.

[4] Richardson, R., 'On the discovery of Arctic Shells at high levels in Scotland,' *Trans. Edin. Geol. Soc.*, vol. iv, 1883, p. 181.

found at Mottram, near Manchester, in till 586 feet above the sea." The specimens referred to have not been traced. This shelly drift is probably similar to that recorded from near Macclesfield.[1]

No glacial striae were observed in this area, but a few have been recorded from the district to the west[2] where they are orientated in a south-east or south-south-east direction.

Distribution of the Drift

In mapping the drift of this area two boundary-lines could be drawn, the one the normal boulder-clay boundary, and the other the limit of distribution of drift pebbles and erratics. This latter approximately coincides with the line of the ice-front at its maximum invasion of the country.

In the north-west corner the maximum height to which the drift has attained is between 1,200 and 1,250 ft. above O.D. and is marked by boulders and pebbles of types foreign to the district. This limit of the drift when traced southwards gradually falls until round Castle Shaw it is not more than 900 ft. above O.D.

Very little boulder-clay has been mapped in this area. In the Tame valley, which from Denshaw past Slackcote and Linfitts to Delph contains several sections, there is no sign of drift. In the valley just west of Castle Shaw boulder-clay occupies the bottom from Castle Shaw Lower Reservoir down to Delph. Foreign pebbles were found up to 1,150 ft. above O.D. on the hills west of Delph.

In Harrop Dale boulder-clay lies in the bottom of the valley and extends up the sides to about the position of the 700-ft. contour at Saddleworth. Southwards between Upper Mill and Greenfield boulder-clay again occupies the valley bottom, where it is probably fairly thick. It covers the valley sides in a thin sheet reaching a height of 1,000 ft. above O.D. near the Pots and Pans Stone.

The hill to the north-west of Greenfield Station and the high ground to the west must have been crossed by the ice, since erratics were found on them, and a small patch of boulder-clay exists on the lee side of the hill above Greenfield, at 1,050 ft. above O.D.

In the valley of the Greenfield Brook boulder-clay extends up to Ashway Gap, reaching a height of 875 ft. above O.D., while the limit of erratics is about the 1,000-ft. contour. Near the lower end of Chew Brook, a tributary of Greenfield Brook, is a purple-brown clay with small pebbles. In the main valley between Greenfield and Copley boulder-clay occupies the valley floor and is probably 50 ft. or more in thickness. From the steep eastern slopes of the valley all the drift above about 800 ft. has slipped or been washed away, but between Warlow Pike and Buckton Castle where the slopes are gentler erratic boulders,

[1] 'Geology of the Country around Macclesfield' (*Mem. Geol. Surv.*), 1906, pp. 125-126.

[2] 'The Geology of Manchester and the South-East Lancashire Coalfield' (*Mem. Geol. Surv.*), 1931, p 179.

some of large size, occur up to altitudes of 1,125 and 1,175 ft.[1] and also on the top of Harridge Pike at 1,293 ft. Boulders occur in Swineshaw Brook as far up as North Britain.

The ice crossed Hollingworthhall Moor leaving erratics scattered about and, in dead ground above 1,000 ft., patches of boulder-clay. The main boundary of the boulder-clay runs round the south side of the moor into the Etherow valley. The drift limit crosses Arnfield Moor at about 1,175 ft. above O.D., boulder-clay extending up to 900 ft. on Arnfield Low Moor, and falls gradually to Crowden. Erratic boulders occur on Boar Flat and Arnfield Moor at over 1,000 ft. above O.D. and on Tintwistle Low Moor at the same height. Boulder-clay in the valley bottom near Arnfield Reservoir is 25 ft. or more thick. Above Tintwistle boulder-clay occurs only in small patches at intervals along the valley bottom. The following suite of specimens was obtained from boulder-clay on the side of Valehouse Reservoir below Deepclough:—Borrowdale rhyolite, andesite and tuff; Buttermere granophyre; Skiddaw and Criffel granite; quartz-porphyry; basalt; and Trias pebbles.

The most easterly erratic observed in the Etherow valley was a large boulder of tuff near the top of Crowden Reservoir. No evidence of glaciation beyond this point has been obtained, and the position of this boulder may be due to rafting. Messrs. Jowett and Charlesworth mention,[2] however, that the drift limit extends to a point about a mile east of Crowden where its height is 900 ft. above O.D.

On the south side of the Etherow thin gravelly boulder-clay, together with several large erratics, was observed up to 800 ft. above O.D. around Hadfield. The ice appears to have reached a height of 1,125 ft. on Blake Moor, north-east of Glossop.[2]

East of the town erratic pebbles were observed just above Moorside at 800 ft. above O.D. and in Shelf Brook at 750 ft. above O.D., but Messrs. Jowett and Charlesworth give 900 ft. as the drift limit here.[2]

In this Glossop embayment boulder-clay covers most of the ground below the 800-ft. contour. Sections, however, are scarce. Two to three feet of purplish-brown clay were seen beneath river gravel in the banks of Shelf Brook at the Borough boundary, and eight feet containing erratics, one of which was a granite, in the south bank of Hurst Brook, a quarter of a mile west of Hurst Mill. In the town itself the boulder-clay is from 5 to 8 ft. thick except on the higher ground.

Sand and Gravel

There are several small areas in the south-west corner of the district which are covered by spreads of glacial sand and gravel. Where seen the sand is yellow and bedded, and contains occasional lenticles of gravel, and, more rarely, bands of clay or silt.

[1] Jowett, A., and J. K. Charlesworth, *op. cit.*, p. 318.
[2] *Op. cit.*, p. 318.

Such deposits have been mapped along the Tame valley down to Mossley, but exposures are rare. The only one of any importance seen was in the patch of sand at New Delph, where 30 ft. of yellow bedded sand with gravelly layers occupies the bottom of the small narrow valley which extends from near Dale to its junction with the main valley at New Delph Bridge. In and south of Mossley there are larger spreads of sand which, however, are unexposed. Three small patches to the east of the Mossley-Millbrook road have been mapped at levels between 570 and 710 ft. above O.D. From Millbrook to Copley a large spread of similar deposits follows the trend of the valley, a smaller one exists immediately north of Sidebottomfold and another to the north-west of Harrop Edge near the Roe Cross gap.

Most of these patches have in time past been dug for sand and gravel but the old shallow pits are now completely overgrown.

Fortunately, records of sections in the sand deposit around Hattersley, Shopwell and Fields are still available. Thus the sand-pit on the south side of the Mottram-Hyde road, three-quarters of a mile west of Mottram Church, shows 15 ft. of sand; while two bores, one on each side of the railway three-quarters of a mile west of Broadbottom Station, yielded the following information: on the north side of the railway—soil, 3 ft.; sand, 4 ft. 6 in.; clay marl, 5 ft. 3 in.; sand, 3 ft. 8 in.; clay to 76 ft.; on the south side of the line—top soil, including 3 ft. of gravel, 14 ft.; sand, 10 ft.; clay, 5 ft.; sand, 4 ft. 6 in.; clay, 50 ft. East of this spread of sand there are a few patches between Broadbottom and Glossop. A sand-pit between Melandra Castle and the River Etherow exposes 25 ft. of sand with fine gravel lenticles. Irregular veins of iron oxide seam the sand. About half a mile downstream on the same side of the river 32 ft. of sand is seen, with occasional silt and clay bands; the whole is overlain by 12 ft. of clay containing many pebbles. Just east of Brookfield in old gravel-pits obscure sections show 22 ft. of sand and gravel with lenticles of clay. Another pit, 350 yards north of Hobroyd, showed in a poor section, upwards of 20 ft. of sand with some gravel and pebbles. In these exposures the sand is medium grained and contains many pellets of rolled shale and fragments of coal. Some parts of these sand deposits are current bedded, and in places they underlie boulder-clay, as at the exposure south of Melandra Castle. In general character and distribution they appear to be of morainic origin.

Retreat of the Ice

In the early stages of the retreat the melt-waters accumulated between the ice-front and the steep western flanks of the Pennines, forming a series of extra-glacial lakes. It is from the survival of the channels formed or modified by the overflow waters from these lakes that the sequence of events may be deduced.

In this district the first stage in the retreat was marked by the existence of two of these lakes, one impounded in the valley of the Tame and extending up its tributary valleys Harrop Dale and that of Greenfield Brook, and the other in the valley of the Etherow drowning part of Longdendale and the lower-lying ground around Glossop.

The highest of the overflow channels which functioned as outlets to the surplus waters of Lake Tame is the one about a mile north-north-west of Denshaw. The channel is well marked but is now partly occupied by the Rooden Reservoir embanked at both ends. The intake to this channel must have been 1,125 ft. above O.D., and it drained northwards into another extra-glacial lake occupying the head of the Ogden valley. Lake Tame at this stage, therefore, belonged to the Walsden Series of Messrs. Jowett and Charlesworth,[1] all the overflow waters of which eventually drained eastwards through the Walsden Gorge.

Later phases in the history of Lake Tame are so far indeterminate. Messrs. Jowett and Charlesworth state that the second phase was determined by the Holly Bank overflow channel which lies just outside the western edge of Sheet 86, one mile north-west of Mossley.

In the Manchester Memoir[2] it is stated that this channel is "largely pre-glacial and has been only comparatively slightly deepened by glacial waters." In addition, there is no evidence to show in which direction the water flowed through the channel and none is forthcoming from the area surveyed for this map. Consequently the sequence of levels of Lake Tame during the later stages of retreat cannot be deduced from the evidence so far accumulated.

The highest outlet used by the overflow from the lake occupying the Etherow valley is at North Britain where it cuts across the high neck of land connecting Boar Flat with Hollingworthhall Moor into the Swineshaw valley. The intake was at about 1,010 ft. above O.D. and the outlet on the Swineshaw valley side can be traced down to about 920 ft. above O.D. There is, however, no sign of deltaic deposits at or below the outlet by means of which the level of Lake Tame during the period of operation of the overflow can be computed.

The next phase in the history of Lake Etherow was determined by the retreat of the ice from Ludworth Moor and the opening of a col at Ludworth Intakes, 2 miles south of Broadbottom and therefore beyond the margin of Sheet 86, which was lower than that at North Britain. This outlet functioned at a level of 890 ft. above O.D. and conducted the overflow waters southwards into the Rudyard Series of extra-glacial lakes.[3]

Messrs. Jowett and Charlesworth[4] point out that there probably was an interval in the history of Lake Etherow in which the lake

[1] *Op. cit.*, p. 321.
[2] *Op. cit.*, p. 182.
[3] Jowett and Charlesworth, *op. cit.*, p. 322.
[4] *Op. cit.*, p. 323.

again drained northwards into the Walsden Series of lakes through the notch at Roe Cross. The height of this gap is about 850 ft. above O.D.; but its natural features are obscured owing to quarrying and road construction.

Later phases of the retreat, if they affected the area, have left no distinctive traces from which their nature and extent may be inferred.

Deposits that can be directly associated with these extra-glacial lakes are not well developed within the area covered by the Glossop Sheet. Since the completion of the re-survey a temporary excavation at the Cricket Field, Road End, Greenfield, 750 yards south-east of Greenfield Station, has revealed the following section:—coarse gravel with cobbles of grit and foreign rocks (including Eskdale granite and Borrowdale volcanics), 6 ft.; red-brown, soapy-textured laminated clay, 0-3 ft.; running sand, not bottomed.[1] The gravel is a post-Glacial terrace, containing rocks washed out of the boulder-clay. This lacustrine deposit is about 525 ft. above O.D. At the time of the original survey a "fine laminated sandy shale" was noticed in Greenfield Brook and along the left bank of the Tame above Stalybridge; it was regarded as a part of the Boulder Clay series.[2]

East of the main Pennine escarpment the country represented on this map appears never to have been invaded by an ice-sheet; no erratics have been recorded from it, and its general aspect is that of a typically unglaciated area. But at several localities there exist patches of a material resembling boulder-clay, a sandy and gravelly clay full of boulders and fragments of sandstone and grit. All the constituents are of local derivation, but in some cases they show by their character that they must have been transported some distance from their source.

Such deposits occur at Shaw Clough, north-east of Pike Lowe and one and a half miles south of Upper Midhope; at Fenny Common Ings, a few hundred yards to the west; near Earnshaw, west of Ewden; on the south side of Harden Clough, north-east of Dunford Bridge; and at the foot of Torside Clough in Longdendale.

Most of these deposits lie at the bottom of long gentle slopes where they were probably accumulated under Glacial or sub-Glacial conditions by the thawing of the surface layers in summer and the consequent downhill flow of the semi-liquid mud so formed over the still frozen subsoil. This may also account for the distribution of scattered boulders of grit which have travelled some distance from their parent outcrop, as, for instance, in Wessenden.

Peat

The peat-mosses of the higher ground are formed by the growth and decay of cotton-grasses (*Eriophorum vaginatum* and *angustifolium*), associated with Crowberry (*Empetrum nigrum*),

[1] We are indebted to Mr. Fred Allen for calling our attention to this section.
[2] 'Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 47.

Whortleberry (*Vaccinium myrtillus*), Cloudberry (*Rubus chamaemorus*) and other plants. The peat is fibrous and of low density; it occurs as a layer 2 to 12 ft. thick, the greatest thicknesses being on the highest, almost level mosses. The average thickness is about 6 feet, but in the south-east of the sheet the sloping moors are covered by only 2 to 3 ft. of peat. Here Ling (*Calluna vulgaris*) is the dominant plant, owing to the good drainage; its remains enter largely into the composition of the peat, which is somewhat more compact than that formed of cotton-grass. Ling also grows freely on all but the wettest mosses in this south-eastern area.

Roots and trunks of trees, chiefly birch and oak, are common in the bottom of the peat all over the area, up to an altitude of about 1,600 feet. Trees probably grew in sheltered spots at slightly higher altitudes. Large trunks and roots of pine are abundant in the base of the peat just south of Pike Lowe, at 1,500 feet. Apart from very rare stunted bushes of Scots pine and birch, growing on the surface of the peat, the high moors are now treeless.

Nearly everywhere the peat is wasting. It is removed in wet weather from the crumbling sides of the channels by which the mosses are intersected. On flat ground these channels tend to spread so as to form a network enclosing irregular mounds of peat, and at this stage the denudation is aided by wind-action in dry weather. A later stage in the destruction may be seen on Black Hill and Bleaklow Hill, where low mounds of peat, supporting little or no vegetation, are surrounded by a maze of wide channels.

The peat appears to act as a sponge, absorbing water in wet weather and parting with it slowly in dry weather. There is a certain amount of sub-peat drainage, water soaking out at the junction with the weathered rock surface and in places flowing from tunnels at the base of the peat.

Should the peat ever be removed from this area the effect on the drainage of the moors would presumably be to accelerate the run-off, while at the same time ending the rapid accumulation of peat-mud in the reservoirs.

The peat must be regarded as post-Glacial, for while the plant-remains in it show no signs of the former existence of boreal conditions[1], flint implements of Maz d'Azil–Tardenois age have been found below it and relics of later ages within it (see below).

Ancient Flint Workings

Worked flints have been obtained from several places on the high moorlands to the south and west of Marsden, in every case above the thousand-foot contour. March Hill, two and a half miles north-west of Marsden, has proved to be one of the most

[1] Burrell, W. H., 'Pennine Peat,' *The Naturalist*, May 1924; and T. W. Woodhead and O. G. E. Erdtmann, 'Remains in the Peat of the Southern Pennines,' *The Naturalist*, 1926, pp. 245-253.

prolific sites along the whole of the Pennines. Some six thousand flint chips have been obtained there within recent years, of which five hundred appear to show clear evidence of human workmanship. Other flint-working sites in this neighbourhood are Lurden, Lominot, and Broadhead Noddle on Castleshaw Moor; while sites have been discovered on Standedge Moor, Pule Hill, Warcock Hill (a small hill just south of Pule Hill and one and a half miles south-west of Marsden) and on West Nab, Meltham Moor.

Both implements and chippings seem to be rare on the high ground to the south. During this survey a single flint flake was picked up at about 1,430 ft. above O.D. 200 yards south of the main road at Hollin Brown Knoll, Saddleworth Moor; another flake was discovered on Shelf Stones, 3½ miles east of Glossop.

All the flints are grey, quite distinct from the black type of the southern chalk flints, and must therefore have been brought from the Lincolnshire or Yorkshire Wolds.

The majority of the worked flints are referable to the Maz d'Azil and Tardenois types and therefore date from a transition period connecting the Palaeolithic and Neolithic periods.

One of the most important sites on Warcock Hill has been excavated and the following detailed section was recorded[1]:—

Cotton-grass peat; at 1 ft. 6 in. from surface fragments of Romano-British pottery; at 2 ft. 5 in. Bronze Age arrow-heads and a piece of bronze; from 2 ft. 7 in. to base, peat with abundant remains of birch and oak, late Neolithic tools, including a leaf-shaped arrow point of the Dolmen type, and horn-cases of *Bos primigenius* . . . 3 ft.

Underlying the peat was a layer of sand and disintegrated sandstone some few inches thick, in which occurred the worked flints and chippings.

The flint implements and chippings of this district fall into two series; the earlier is unpatinated, the later patinated. Both are found in the layer of disintegrated rock at the base of the peat, that is the layer containing relics of the birch-oak forest. The conclusion has been drawn that the earlier series coincides with a dry boreal climate, in which the forest flourished, the later series with the moist cold 'Atlantic' period, which killed the forest and gave rise to the growth of peat.[2] This change of climate is deduced from evidence covering the greater part of north-west Europe. In the lowest layer of peat Neolithic remains are found, and above them relics of the Bronze Age, the most notable site within our area being Warcock Hill, Marsden; Bronze Age burials are known at Pule Hill and elsewhere.[3] Considerably higher, about the middle of the peat, is apparently the level of the Roman paved way over Blackstone Edge, about

[1] Woodhead, T. W., 'History of the Southern Pennines,' *Journal of Ecology*, vol. xvii, 1929, pp. 15, 16.

[2] Woodhead, T. W., *Journal of Ecology*, vol. xvii, 1929, pp. 1-34.

[3] Buckley, F., 'Microlithic Industry of Pennine Chain' (Privately Printed), 1924; J. A. Petch, 'Early Man in the District of Huddersfield,' Huddersfield Museum, 1924.

two and a half miles north of our boundary,[1] but no evidence in support of this correlation is available in our area.

Topographic Development

From the above accounts it will be seen that the events of the Glacial epoch have had comparatively little observable effect on the shaping of the ground, except on the extreme western margin. On the eastern slopes of the Pennines there was apparently no moving body of ice west of the margin of the Vale of York ice-sheet, reached near Barnsley. Within our area, especially in the south, the slope is, apart from dissection by the streams, remarkably even (Fig. 17; see also horizontal section on the map), and appears to be an ancient peneplain; but there is nothing to indicate its age. Taking into account a much larger area than can be dealt with here Professor Fearnsides has

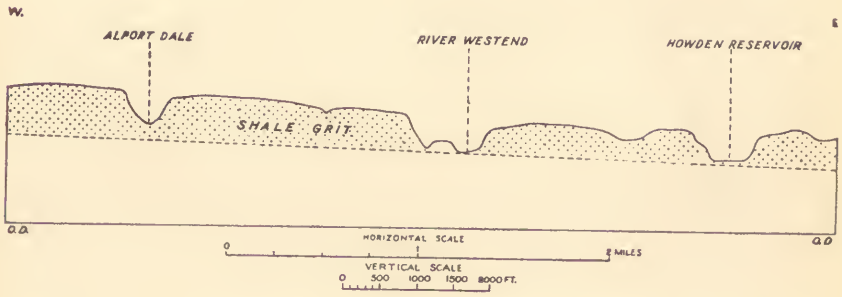

Fig. 17.—*Section of the dissected plateau of Shale Grit across Alport and Westend Moors.*

recently suggested that this plane may be a denuded relic of that formed at the end of the Carboniferous period, on which the Permian formation was laid down farther east. During Permian times the shore-line lay several miles to the east but advanced gradually westwards in the Triassic, Jurassic and Cretaceous periods, at some time during which the Pennine area was completely submerged.[2] On the other hand Dr. Trotter considers that a similar peneplain on the Alston Block was produced in late Tertiary times.[3] No evidence is available to decide how much further planing of our area occurred in this period.

When this ancient surface was again uncovered the drainage would be by consequent streams. Examples of these remain in the Colne or Marsden Brook, the Meltham Brook, the upper part of the Holme, the Don, Little Don and Ewden Beck, all

[1] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 139.
[2] Fearnsides, W. G., and others, 'Geology of the Eastern Part of the Peak District,' *Proc. Geol. Assoc.*, vol. xliii, 1932, pp. 152-191.
[3] Trotter, F. M., 'Tertiary Uplift and Resultant Drainage of the Alston Block,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, pp. 161-180.

rising on the grit moors, and in the Dearne (flowing through Denby Dale), the Gunthwaite Brook and the stream flowing from near Pike Low to Ingbirchworth (the Broadstone Dike), rising on the Coal Measures. On the west the Greenfield Brook and the Etherow are consequent streams.

W. Lower Carter has given reasons for thinking that the Don and Little Don at one time continued their courses down the dip-slope beyond the present area, the former passing between the high ground at Hoyland Swaine and at Thurgoland, and so down what is now the valley of the Dove. A little below Penistone the Don now bends southwards towards Sheffield and receives the Little Don and the Ewden Beck as tributaries on its right bank, being in this part of its course a subsequent or strike stream. Within our boundaries the Broadstone Dike makes a similar turn at Ingbirchworth and from that point to the confluence with the Don is known as the Scout Dike; this is presumably a case of river-capture by the rejuvenated Don, the original course being eastward into the Gunthwaite Brook.[1]

The Holme continues as a dip stream from its sources till it encounters the Lower Coal Measures escarpment below Thurstonland and then becomes a strike stream, receiving the Meltham Brook just before leaving the area. The latter is a dip stream whose course is partly determined by the Meltham syncline (p. 122). It is possible that the subsequent stream occupying the Wessenden valley and joining the Colne at Marsden has robbed the Meltham Brook of some of its headwaters, the tributaries on the right bank being reversed obsequents.

Whatever the date of these changes, the high ground throughout the area has the appearance of a young and immature topography. Large parts of the original peneplain remain, and the cloughs show signs of recent rejuvenation. They are V-shaped and have steep thalwegs, noticeably stepped when they pass from the hard grits to the softer shales, the former producing short temporary base-levels on account of their resistance to erosion. Where a main stream has cut its valley to a considerable depth the tributaries usually enter by cascades from near the summit level, forming hanging valleys similar to those entering valleys formerly occupied by glaciers.

The River Etherow may fairly be taken as an epitome of recent stream-development in this area. It behaves as a fairly simple consequent stream, draining westwards off the Pennine upland. Its headwaters rise on the south and north sides of the Holme Moss and Bleaklow plateaux respectively and descend across the Kinderscout Grit in V-shaped gorges to their confluence at Woodhead. Rapid headward development is proceeding along these gorges,

[1] Carter, W. Lower, 'Evolution of the Don River-System,' *Proc. Yorks. Geol. Soc.*, vol. xv, 1905, pp. 388-410.

the bare rock being swept clear of all debris except large foundered blocks from the oversteepened valley sides (cf. Plate IIA). Below Woodhead the river flows in a wide valley cut down into Grindslow Shales and Shale Grit; the valley sides slope up to the steep edges of the Kinderscout Grit plateau 600 to 900 ft. above. Along parts of its course the river has established temporary base-levels for short distances, but these are interrupted by faulted inliers of Shale Grit, at each of which the valley bottom narrows to a gorge-like form (now obscured by reservoir dams). There are several spectacular examples of hanging tributaries falling over the southern edge of the valley, which is formed by the strong basal bed of the Kinderscout Grit. Wildboar Clough, for example, only falls 300 ft. in the 1,800 yards between its source on Bleaklow and the valley edge, but falls over 900 ft. in the 1,600 yards between there and the Etherow. Only the largest of these streams, Torside Clough, has breached the valley side to any extent. On the north side of the valley the Crowden and Heyden brooks come in at grade, and in their upper courses display the same features as the Etherow headwaters. Below Tintwistle the Etherow leaves the plateau region and meanders between alluvial terraces on a lower temporary base-level as far as Broadbottom, where it cuts through the Rough Rock in a gorge on leaving the area described for the low drift-covered plain of Cheshire.

Effect of Glacial Period on rivers.—The river system was developed in all its main features in pre-Glacial times, and since then has only been altered in minor details. The river valleys do not seem to have been modified by glaciers, or if they have, all trace of such modification has been since removed by denudation. It is, however, not out of place to speculate on the differential erosion of the valleys by solifluxion during some part of the Glacial period (see also p. 135). The great power of this process as an erosive agent under glacial or sub-glacial conditions has been emphasized by many observers. In the present area, given the right conditions of temperature and precipitation, its action must have been drastic but at the same time highly capricious. While the plateaux of grit would stand almost untouched, the long shale slopes, already bared by the pre-Glacial rivers, may well have suffered enormous denudation, being shorn summer by summer of successive thick layers, which slumped into the valleys as mud-flows and were carried away by the snow-swollen torrents. Such action would accentuate the step-like topography of the moors and the irregular thalwegs of the immature rivers. It would in particular sharpen valley features by oversteepening the shale slopes, and leave behind it the necessary conditions for the formation of extensive landslips, the ancient debris of which cumber the sides of so many valleys. Landslipping, while going on at the present day, appears to have been most active at some past date nearer Glacial times.

River Capture at Woodhead.—A case of rapid headward development resulting in river-capture is provided by Far Black Clough, one mile south-east of Woodhead Station. (See Fig. 18.)

The upper waters of this clough originally entered the Etherow through Swan Clough. From the first the larger volume of water

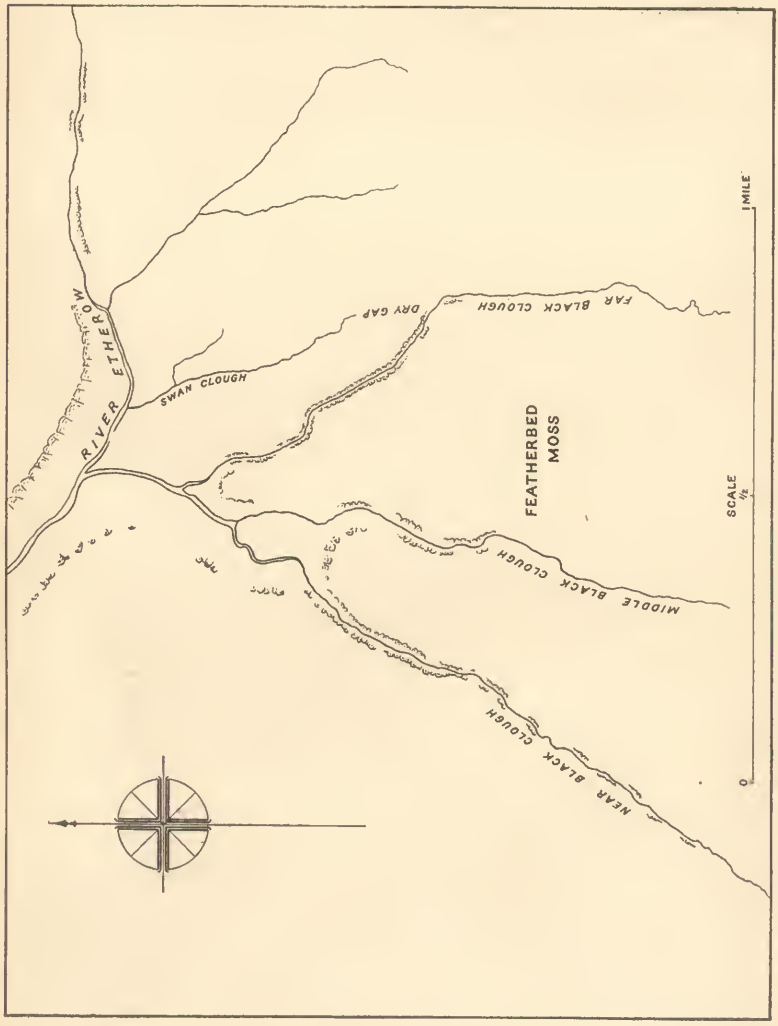

FIG. 18.—*Map showing relationship between Far Black Clough and Swan Clough.*

passing down Near and Middle Black Cloughs gave them an advantage in corrasion over Swan Clough, although while they were cutting into Kinderscout Grit the latter ran for part of its lower course over a shale parting in that formation. Eventually the shale was cut through and hard grit exposed, and meanwhile the Black

Cloughs exposed a faulted window of shale beneath the Kinderscout Grit, just below their junction; working in this soft material they quickly cut this part of their bed down to grade with the Etherow. A small tributary (Far Black Clough) joined the united streams at this window and was thus given such a steep slope that it cut back its head to the point of intercepting at a lower level the waters of Swan Clough.

The diverted waters have cut a deep rock-walled gorge, while the beheaded remnant of the original valley is occupied by a tiny trickle which wanders among the overgrown debris of the former stream-course. The date of this river-capture is considerably post-Glacial.

CHAPTER VII

PALAEONTOLOGY

In the Upper Carboniferous rocks of the Holmfirth district, the most abundant fossils are goniatites, lamellibranchs and plant-remains; the last are usually in a poor state of preservation, but are abundant at certain horizons, more particularly in the Coal Measures.

The marine fossils including the goniatites do not occur throughout the general mass of the measures. They appear to be confined to thin bands of black or bluish-grey siltstone, mudstone or shale, termed marine bands. In these bands, often not more than a few inches in thickness, the fossils are generally exceedingly abundant. Within the Millstone Grit Series there are some ten distinct marine bands, while in the Coal Measures they only occur at three horizons and these are confined to the lower part of the measures.

For the purposes of correlation and classification both the goniatites and lamellibranchs have been found to be of great value. It was within the limits of the present area that Mr. Bisat originally worked out a zonal succession of goniatites,[1] which has since been found applicable not only to adjacent districts, but to areas still farther afield.

Within the Millstone Grits and the lower part of the Coal Measures the marine lamellibranchs consist chiefly of species of *Pterinopecten* and *Posidonomya*, together with a few examples of *Posidoniella* and *Aviculopecten*. Until recent years species of *Pterinopecten* have been recorded under the comprehensive term *Pterinopecten papyraceus* (J. de C. Sow.). This form is typical of the Coal Measures; but earlier species have now been separated by Dr. J. W. Jackson, who finds that many of them have a limited vertical range and can thus be used to supplement the goniatite succession for the purposes of zoning.[2]

In the Coal Measures marine bands are so infrequent that they cannot be employed for the classification and correlation of these rocks. Numerous bands occur, however, in which the fauna consists mainly of lamellibranchs referred to the genera *Carbonicola*, *Anthracomya* and *Naiadites*, which are believed to have lived in fresh and brackish waters. Within recent years a detailed study of these forms has been made, and it is now possible to employ them as a basis for a broad classification of the Coal Measures, which can be used in correlating, in a general way, the measures in adjacent coalfields.

[1] Bisat, W. S., 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, pp. 40-124.

[2] Jackson, J. W., 'New Carboniferous Lamellibranchs and Notes on other Forms,' *Mem. and Proc. Manch. Lit. and Phil. Soc.*, vol. lxxi, 1927, pp. 93-122.

The Goniatite Zones

In practically all the marine bands in the Millstone Grits and the Coal Measures goniatites are the most abundant and characteristic members of the fauna. These goniatites are all referable to the family Glyphioceratidae, and the principal genera represented are *Reticuloceras, Gastrioceras* and *Anthracoceras*. The latter is practically unrecognized within the present area. The genus *Reticuloceras* Bisat, of which the genotype is *Reticuloceras reticulatum*[1], characterizes the marine bands of the Millstone Grit of this area with the exception of those above the Middle Grits. The top of the Middle Grit group marks a very definite dividing line, for in each of the marine bands above it the dominant genus is *Gastrioceras*. Although the goniatites are relatively abundant in the marine bands, they are usually only represented by crushed impressions; but at each fossiliferous horizon one form usually predominates to such an extent that its identification is greatly facilitated, although the specimens are often fragmentary and in a comparatively poor state of preservation. The test ornament is, however, usually well preserved and Mr. Bisat's work[2] has shown that this furnishes a very delicate and reliable evolutionary index. Each marine band contains specimens of varying ages and stages of growth which can readily be referred to one species and thus the differences due to age can be studied in some detail. Occasionally nodules containing goniatites occur in the marine bands and furnish uncrushed specimens exhibiting suture-lines, the shape of the shell, and sometimes finer markings on the shell, not well preserved in specimens obtained from the shaly matrix.

The Range of *Reticuloceras reticulatum*

This species is a characteristic upper Millstone Grit form, and in the marine bands occurring in shales above the Kinderscout Grit and also in the Middle Grit Series the several mutations of this species are by far the most abundant fossils found.

The lowest marine band within the limits of the present one-inch map occurs in a shale parting in the upper part of the Kinderscout Grit. This horizon however yields no goniatites. In the thick series of Grindslow Shales which underlies the Kinderscout Grit we have been unable to discover any marine horizons. In the Todmorden[3] and Crimsworth Dean[4] districts to the north, however, fossiliferous horizons occur in the shales underlying the Kinderscout Grit, and yield in addition to other forms *Reticuloceras reticulatum* (Phillips), type form as defined by Mr. Bisat. In 1896 Messrs. W. F. Holroyd and J. Barnes published a description of the geology of the Saddleworth

[1] Phillips, J., 'Geology of Yorkshire: Part ii, The Mountain Limestone District,' *London*, 1836, p. 235 and plate xix, figs. 26-32. W. S. Bisat, *op. cit.*, p. 114, pl. iv, figs. 1, 2.
[2] *Op. cit.*
[3] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 126.
[4] 'The Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 142.

district,[1] and recorded fossils from Greenfield in beds below the Kinderscout Grit. On the original Geological Survey map of this district these rocks are referred to as the Yoredale Series, and Messrs. Barnes and Holroyd also describe them under that name. It is now known, however, that the true Yoredale Series of Wensleydale represents a far lower horizon, and consequently this nomenclature has been abandoned. The fossils found by these two writers came from a series of bullions, and the section is no longer visible nor can it be accurately located; they are preserved in the Manchester Museum, and Dr. J. W. Jackson informs us that they include *Reticuloceras reticulatum*, type form. These fossils, therefore, furnish confirmatory evidence of the equivalence of the shales below the Kinderscout Grit in the Saddleworth district and the Grindslow Shales of Derbyshire and the Todmorden districts.

The Butterly Marine Band.—In the country to the north, and also in the neighbourhood of Marsden the Kinderscout Grit is subdivided into an upper and lower part by a persistent bed of shale which contains a marine band.[2] This marine horizon was first observed by Mr. Bisat in Butterly Clough, Marsden,[3] and has been termed the Butterly Marine Band (see page 15). It has been recognized in the Rishworth, Standedge and Wessenden districts.

With the exception of a single record of *Reticuloceras reticulatum*, mut. α Bisat (=mut. *gracile* Bisat) from this band in the neighbourhood of Red Brook Clough near Pule Hill, no goniatites have been found in it. The fauna consists of brachiopods, lamellibranchs, gastropods and fragmentary fish-remains, including Palaeoniscid scales. The rarity of a goniatite fauna at this horizon is noteworthy, and suggests that this band was laid down under somewhat different conditions from those in the case of the majority of the marine bands in the Millstone Grits.

The brachiopods in this band include *Lingula mytiloides* J. Sowerby, *Lingula sp.*, and *Orbiculoidea nitida* (Phill.). Lamellibranchs are very numerous and include the following species:—*Aviculopecten* cf. *carboniferus* (Stevens), *Aviculopecten* cf. *clathratus* M'Coy, *Aviculopecten* cf. *obliquus* Hind; *Edmondia josepha* de Kon., *Edmondia transversa* Hind; *Nuculana attenuata* (Fleming); *Posidoniella* cf. *minor* (Brown), and *Posidoniella* cf. *pyriformis* Hind; *Protoschizodus sp.*; *Sanguinolites occidentalis* (Meek and Worthen), *Sanguinolites ovalis* Hind, *Sanguinolites striato-granulatus* Hind, *Sanguinolites striato-lamellosus* (de Kon.), *Sanguinolites tricostatus* (Portl.); *Sedgwickia attenuata* M'Coy; *Scaldia sp.*; *Schizodus antiquus* Hind, and *Schizodus sp.*

[1] Holroyd, W. F., and J. Barnes, 'On the Rocks and Fossils of the Yoredale Series of the Marsden and Saddleworth valleys,' *Trans. Manch. Geol. Soc.*, vol. xxiv, 1896, pp. 70-99.

[2] 'The Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, pp. 16-17.

[3] Bisat, W. S., *The Naturalist*, 1920, p. 349.

Gastropods also occur frequently in this band and include the following forms :—*Bellerophon costatus* J. Sow., *Bellerophon sp.; Bucanopsis sp.; Bulimorpha flemingi* (Brown); *Euphemus sp.;* and *Rhabdospira* cf. *reticulata* (Brown).

Fossils have been collected from this horizon by the Geological Survey from the following localities within the area of one-inch map, Sheet 86 (Glossop) :—

1. In Red Brook Clough, Pule Holes; 500 yards due west of Pule Edge Quarries, Pule Hill, Marsden.
2. In deep gully at overflow, north-east corner of Red Brook Reservoir, Standedge, 700 yards south-west of Pule Hill, Marsden.
3. In Butterly Clough, 620 yards south of its junction with Carr Clough, and one and a half miles S.S.W. of Marsden Church.
4. Road-cutting along eastern bank of Butterly Reservoir; just south-east of Water House, and 1,150 yards almost due south of Marsden Church.
5. Section at waterfall in Wessenden Reservoir overflow; 250 yards west of Wessenden and one and three-quarters of a mile south of Marsden.
6. Huddersfield Corporation water-boring, Wessenden Head. Horizon : Sixty feet below top of Kinderscout Grit. The site is on the north side of the Huddersfield-Greenfield main road and 720 yards south-west of the ' Isle of Skye ' Hotel.

The Subzone of Reticuloceras reticulatum, *mut.* α.—In the area represented by the present one-inch map (Sheet 86), the highest bed of the Kinderscout Grit is usually overlain by a band of fireclay and a thin coal seam; and these are succeeded by a thick series of dark shaly mudstones. Towards the base of these mudstones, usually a few feet above the coal, a marine band occurs in which the dominant goniatite is *Reticuloceras reticulatum,* mut. α Bisat (= mut. *gracile* Bisat). Other cephalopods which occur in this band include *Dimorphoceras sp.,* and *Orthoceras sp.* The brachiopods include *Orbiculoidea nitida* (Phill.) and *Chonetes* cf. *hardrensis* (Phill.). Lamellibranchs are fairly common, though not many species are represented. They include *Posidoniella minor* (Brown), *Posidoniella rugata* J. W. Jackson, *Pterinopecten speciosus* J. W. Jackson and related forms. *Posidoniella minor* is characteristic of the marine bands below and immediately above the Kinderscout Grit, while *Posidoniella rugata* is practically confined to and characteristic of the marine bands containing *Reticuloceras reticulatum,* mut. α, and early mut. β. The latter band usually occurs within thirty feet or less of the underlying ' mut. α ' band. The species *Pterinopecten speciosus* is practically confined to the subzones of *Reticuloceras reticulatum,* mut. α and mut. β, and is especially abundant in and characteristic of the ' mut. β ' band.

In addition to the foregoing fossils, numerous small gastropods, ostracods and fragmentary fish-remains also occur in the ' mut. α ' band. Fossils have been collected from this horizon by the Geological Survey from the following localities within the area of one-inch map, Sheet 86 (Glossop) :—

1. Section in left bank of stream, sixty yards east of road in Little Moss Gutter, Badger Slack, Castleshaw Moor. About a mile and three-quarters north-east of Denshaw Church.
2. On left bank of Carr Clough, 100 yards south of the Old Moorcock Inn, and one mile south-west of Marsden Church.
3. In small gully on east slope of Butterly Clough, and 750 yards south of its junction with Carr Clough. About one and a half miles south-west of Marsden Church.
4. On left bank of a small tributary on the east side of Butterly Clough, 800 yards south of the junction of Carr Clough and Butterly Clough, Marsden (see Fig. 7, p, 30).
5. On west bank of gorge at top of Butterly Clough, and 270 yards east of embankment wall, Swellands Reservoir. Nearly two miles south-east of Marsden Church.
6. Near junction of Hoe Grain and Shiny Brook Clough; one mile west of the Isle of Skye Hotel, Wessenden Moor.
7. At Howels Head Flat, 600 yards west of Far Broadslate; two and a half miles east of Greenfield House, Saddleworth Moor.
8. Near Broadslate, south of Howels Head (see page 45).
9. Stream section just above bridge, 130 yards south of Holme Woods. One mile south of Holme.
10. At Mickleden, 550 yards north-west of Lost Lad, Midhope Moors. About one and a half miles south-west of Langsett Reservoir.

On the southern slopes of Pule Hill near Marsden there is an excellent exposure of a marine band in the shales above the Kinderscout Grit which is believed to occupy a position closely corresponding to the ' mut. α ' band of adjacent areas. In this band, however, typical ' mut. α ' is not dominant and its place is taken by a variant which is intermediate in character between *Reticuloceras reticulatum,* mut. α and mut. β which is described by Mr. Bisat as late mutation α.[1]

The following fossils have also been collected from this band :—*Dimorphoceras sp., Orthoceras sp., Posidoniella minor* (Brown), *Posidoniella rugata* J. W. Jackson and *Pterinopecten speciosus* J. W. Jackson. The actual site of the exposure collected from is along the north side of Mount Road, and four hundred yards north-east of Gilberts Farm, Marsden.

The Subzones of Reticuloceras reticulatum, *mut.* β.—There are three distinct stratigraphical horizons at which marine bands occur in which the goniatite *Reticuloceras reticulatum,* mutation β [=mut. *bilingue* (Salter)] is the dominant form. Each of these bands is characterized by variants of that goniatite, but it is doubtful whether they represent successive evolutionary stages in its development (see p. 45). Thus in the lowest band the predominant goniatite is usually early mutation β ; in the succeeding one typical specimens of *Reticuloceras reticulatum,* mut. β are most frequent ; although in some areas a variant referred to by Mr. Bisat as late mutation β appears to be the dominant form. In the highest band the characteristic form is usually *Reticuloceras*

[1] Bisat, W. S., ' The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 116.

reticulatum, late mut. β. This marine band occasionally yields in addition forms referred to as early mut. γ by Dr. W. B. Wright.[1]

The lowest of these three bands, which we have called the ' early mut. β band,' has only been found in the northern part of the area, where it occurs about 30 feet above the mut. α and late mut. α band, *i.e.* just over that distance above the top of the Kinderscout Grit, the shales between being barren except for occasional impressions of *Lingula* and *Posidoniella* (Plate IIIB).

Besides the early mutation β, forms occur in this band which are indistinguishable from the typical *Reticuloceras reticulatum*, mut. β Bisat. Other cephalopods include *Dimorphoceras sp.*, *Homoceras proteum* (Brown), *Homoceras striolatum* (Phill.) and *Orthoceras sp.* The lamellibranchs include *Posidoniella minor* (Brown), *Posidoniella rugata* J. W. Jackson, *Pterinopecten speciosus* J. W. Jackson and *Sanguinolites sp.* Brachiopods are also represented by *Chonetes* cf. *hardrensis* (Phill.), *Lingula sp.* and *Productus sp.* Other fossils include crinoid columnals and fragmentary fish-remains.

Fossils have been collected from the ' early mutation β ' marine band at the following localities within the area of one-inch Sheet 86 (Glossop) :—

1. In Dan Clough, southern slope of March Hill, Marsden. 650 yards W.S.W. of Haigh Reservoir.
2. In Green Owlers Clough, 280 yards north of Park Farm, Stack End, Marsden.
3. Southern slopes of Pule Hill; north side of Mount Road, Marsden. Four hundred yards north-east of Gilberts Farm, Marsden.

At Howels Head on Saddleworth Moor, there occurs a nodule band containing exclusively moulds of the late mutation β. The position of this band is 30 ft. above the Kinderscout Grit, and rather less than that distance above the mut. α band. The difficulties concerning this band have been discussed on p. 45, Chapter II.

The mut. β marine band occurs in a band of shale usually from fifty to seventy feet below the base of the Pule Hill Grit or Heyden Rock and immediately above the topmost bed of the Readycon Dean Series where that group is represented. While this marine band has been found to be remarkably persistent in the adjoining country to the north and north-west, it has not been observed on the Midhope and Broomhead moors in the south-eastern portion of the area covered by Sheet 86 (Glossop). The dominant goniatite in this band is usually *Reticuloceras reticulatum*, mut. β Bisat. This form appears to correspond most closely with the goniatite described by Salter as *Goniatites bilinguis*.[2] In some places, however, the most characteristic fossil at this horizon is a form referred to by Mr. Bisat as *Reticuloceras reticulatum*, late

[1] Wright, W. B., ' New Goniatites from the Millstone Grit of Lancashire ' in ' Summary of Progress ' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix viii, p. 194.

[2] Salter, J. W., in ' Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 60.

mutation β[1], a goniatite also common in the succeeding marine band overlying the Pule Hill Grit or Heyden Rock.

Other cephalopods which occur in this marine band include *Eumorphoceras ornatum* (Foord and Crick) and *Orthoceras spp.* Among the latter is an undetermined species of *Orthoceras* from Crowden Little Brook (see page 50) with annular swellings and fine linear ornament. The lamellibranchs include forms closely related to *Posidoniella minor* (Brown) and *Posidoniella rugata* J. W. Jackson, both of which are characteristic of the 'mut. α' and 'mut. β' marine bands. Other fossils occurring at this horizon are ostracods and the gastropod *Ptychomphalus.*

Fossils from this horizon have been collected by the Geological Survey from the following localities within the area of the one-inch map, Sheet 86 (Glossop). In those marked with an asterisk mut. β (type form) is the dominant goniatite. In the remainder late mut. β only occurs and is the characteristic fossil :—

*1. In Black Sike, some six feet above the western bank of Low Reservoir; and half a mile south-west of Upperthong. One mile west of Holmfirth.

*2. Section in main stream, Ramsden Clough; at point where tributary joins right bank. Three miles south-west of Holmfirth.

*3. At junction of Whitelow Slack and Crowden Little Brook, Sliddens Moss, Heyden Moor.

*4. On west bank of Heyden Clough, a quarter of a mile west of the Holme—Woodhead road; and two and a quarter miles south-west of Holme. (On east bank, 30-40 yds. upstream, late mut. β only occurs).

5. Section on right bank of tributary, one hundred yards east of road, Castleshaw Moor. One and three-quarter miles north-east of Denshaw Church.

6. Gorge at head of Butterly Clough, about three hundred yards east of embankment wall of Swellands Reservoir. Two miles south-south-east of Marsden Church.

7. On right bank of small stream in gully, forty yards east of Ox House, and half a mile south-east of Marsden Church.

8. In Black Dike, branch of Dean Clough; Wessenden Head Moor. 1,350 yards south of the Isle of Skye Hotel.

Estuarine Band in the Pule Hill Grit and Heyden Rock.—In the country to the north and east of Marsden, the Pule Hill Grit consists of a lower bed of massive grit and an upper flaggy portion, the two being separated by a band of shale about twenty feet thick. In this shale parting a fossil band occurs, the fauna consisting principally of lamellibranchs, gastropods and brachiopods. Goniatites, usually abundant in the marine bands of the Upper Carboniferous, are apparently absent. From an old quarry on the western side of Varley Road in Slaithwaite, and quite close to Windy Bank Farm, fossils were collected by the Geological Survey from this marine band and included the following forms :—*Cypricardella sp., Edmondia sp., Myalina sp., Nucula sp., Sanguinolites sp.*, and *Scaldia sp.*; *Naticopsis brevispira* (Brown) and *Naticopsis globosa* (von Hoeninghaus); *Lingula mytiloides* J. Sow., and *Orbiculoidea nitida* (Phill.).

[1] 'Summary of Progress' for 1931, Part ii (*Mem. Geol. Surv.*), 1932, pp. 120, 121.

This band also occurs in a corresponding position in the upper part of the Heyden Rock on Heyden Moor. Exposures at a point forty yards north of the waterfall in Crowden Little Brook and elsewhere yield abundant impressions of *Lingula sp.* (see p. 53).

The Subzone of Reticuloceras reticulatum, *late mut.* β.—The highest marine band in which forms referred to *Reticuloceras reticulatum*, mut. β are found occurs in the shales immediately overlying the Pule Hill or Rivelin Grit. This marine band, however, appears to be absent from the strata at this horizon on the moorlands about the centre of the sheet. The top of the Pule Hill or Rivelin Grit is well defined, a thick bed of fireclay usually overlying it, and not infrequently a thin coal seam. The marine fossils are confined to a comparatively thin band a few feet above the coal, where present. The dominant goniatites are forms ranging from the typical *Reticuloceras reticulatum*, mut. β of Mr. Bisat to advanced forms described by that author as late mutation β. At Meltham and on Midhope Moors it also includes forms described by Dr. Wright as early mutation γ (=mut. *metabilingue* W. B. Wright).[1]

The remaining cephalopod fauna of this bed is somewhat limited, including *Homoceras proteum* (Brown), and undetermined species of *Orthoceras* and *Dimorphoceras*. The other fossils consist almost entirely of lamellibranchs. *Posidoniella laevis* (Brown) is a very characteristic species, while the remainder include forms closely related to *Posidonomya insignis* J. W. Jackson and *Posidoniella rugata* J. W. Jackson.

Fossils from this horizon have been collected by the Geological Survey from the following localities within the area of the one-inch map, Sheet 86 (Glossop):—

1. In Harden Clough, 250 yards. east of Foxroyd, and 1,400 yards south of Meltham railway station.
2. Four hundred and fifty yards north-north-west of Barrow (Pike Lowe), Midhope Moors.
3. Two hundred and fifty yards north-east of Ewden Lodge, Ewden.
4. On west bank of Rocher Head Brook, 550 yards north-north-east of Frost House, and 1,500 yards south-west of West Nab. Two miles south of Bolsterstone Church.
5. Two hundred and twenty yards south-east of Canyards, and three-quarters of a mile south-east of Smallfield, Broomhead Moor.
6. At south end of Tunnel at Scout, and behind Scout Mill, Mossley.

The Subzone of Reticuloceras reticulatum, *mut.* γ.—The marine band characterized by *Reticuloceras reticulatum*, mut. γ (=mut. *superbilingue* Bisat) appears to have a very wide distribution throughout the area under consideration. Along the western margin of the present one-inch map between Denshaw and Delph it occurs a short distance above the top of the Hazel Greave Grit, while in the Meltham district it is found in a corresponding position above the Beacon Hill Flags; the latter being clearly the local representatives of the Hazel Greave Grit

[1] *Op. cit.*, p. 194.

of East Lancashire.[1] The marine band also occurs above the Beacon Hill Flags in the neighbourhood of Midhope Moors; while on the moors around Wessenden and Holme, where the Beacon Hill Flags are unrepresented, the same marine horizon occurs in the thick shale series below the Huddersfield White Rock, usually thirty to forty feet below the base of that sandstone.

In addition to the zonal fossil *Reticuloceras reticulatum*, mut. γ, which is the dominant member of the fauna, the genus *Gastrioceras* first appears at this horizon. It is not abundant, but includes forms closely resembling *Gastrioceras cancellatum* Bisat in ornament, and at Black Dike on Wessenden Head Moor an isolated specimen of *Gastrioceras cancellatum* has been obtained, though it does not appear to be present elsewhere. The forms of *Gastrioceras* usually present include two species described by Dr. Wright respectively as *Gastrioceras lineatum* and *Gastrioceras ? sigma*.[2] The latter are often found in a distinct band occurring from two to ten feet above the main marine band with *Reticuloceras reticulatum*, mut. γ, though in some places, as on Midhope Moors, it occurs in the upper part of the main marine band.

At Robert Clough near Upperthong the *Reticuloceras reticulatum*, mut. γ band occurs about sixty-five feet below the Huddersfield White Rock and on the top of the Heyden Rock. Here the marine band is over four feet thick, and in the lower layers *Reticuloceras reticulatum*, mut. β has been found, though it appears to be rare. With it are also associated forms described by Dr. Wright as *Reticuloceras reticulatum*, early mut. γ (or *metabilingue*).[3]

In the country to the north *Reticuloceras reticulatum*, early mut. γ is practically confined to and distinctive of the marine band characterized by *Reticuloceras reticulatum*, late mut. β, which overlies the Pule Hill Grit of that district.[4] To the south, however, it has also been found in the 'mut. γ' band at Hingcliff Scar, near Langsett.

Other cephalopods which occur in the *Reticuloceras reticulatum*, mut. γ marine band include *Dimorphoceras sp.*, *Homoceratoides divaricatum* (Hind), *Orthoceras* cf. *asciculare* (Gibson MS.) Brown, and *Orthoceras sp.*

The lamellibranchs found in this marine band include *Posidoniella* cf. *gibbosa* Hind, *Posidoniella laevis* (Brown), and forms closely allied to *Posidoniella minor* (Brown) and *Posidoniella rugata* J. W. Jackson. The two last-named forms are more frequent in the lower marine horizons characterized by

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[1] Wray, D. A., 'The Carboniferous Succession in the Central Pennine Area,' *Proc. Yorks. Geol. Soc.*, vol. xxi, 1929, p. 242.
[2] *Op. cit.*, pp. 196, 197.
[3] Wright, W. B., *op. cit.*, p. 194.
[4] 'The Geology of the Country around Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 148.

mutations of *Reticuloceras reticulatum*. Other lamellibranchs are *Posidoniella* cf. *multirugata* J. W. Jackson, *Posidonomya sp.*, *Pterinopecten elegans* J. W. Jackson, *Pterinopecten* aff. *carbonarius* Hind and *Pterinopecten speciosus* J. W. Jackson. *Pterinopecten elegans* does not occur in the lower marine bands characterized by *Reticuloceras reticulatum*, though it is well represented in the *Gastrioceras cancellatum* and *G. cumbriense* marine horizons in the shales above the Middle Grits. *Pterinopecten speciosus*, on the other hand, is confined to the several subzones of *Reticuloceras reticulatum* occurring in the Middle Grit Series.

The remaining fossils in the 'mut γ' marine band are brachiopods, including *Lingula mytiloides* J. Sowerby, and ostracods. At Upperthong several fish-remains were obtained, including Palaeoniscid scales, and others referred to the genus *Coelacanthus*, together with *Elonichthys aitkeni* Traquair.

Beneath the 'mut. γ' marine band at Linfitts Mill near Delph, the shales yielded abundant plant-remains including *Artisia sp.*, *Calamites suckowi* Brongniart, *Calamites sp.*, and *Cordaites sp.* Fossils from this horizon have been collected by the Geological Survey from the following localities within the area of the one-inch map, Sheet 86 (Glossop):—

1. On right bank of stream in Slackcote Lane, 200 yards east of Slackcote Mill, and just over a mile north-west of Delph.
2. On right bank of River Tame, 250 yards north of Linfitts Mill, and three-quarters of a mile west-north-west of Delph.
3. Small disused quarry, north of Beswick, and 750 yards west of the Church, Delph.
4. Bradley Brook Clough, White Heaps, Holt Head. Immediately below the Blackmoorfoot conduit, 500 yards north-east of north-eastern corner of Deerhill Reservoir, and about one mile east of Marsden.
5. Shales overlying ganister rock in quarry on Banister Edge; about one and a quarter miles south-west of Meltham railway station.
6. North bank of stream, Robert Clough; three-quarters of a mile W.S.W. of Upperthong and a mile west of Holmfirth.
7. At head of Black Dike, 2,000 yards S.S.E. of Wessenden Head, Wessenden Head Moor.
8. Near top of Hey Clough, and 200 yards south-east of the triangulation point on Black Dike Head, Wessenden Head Moor.
9. At fork in stream, Great Twizle Hole, 1,450 yards south of Yateholme and one and a quarter miles south-south-west of Holmbridge Church.
10. Left bank of brook, Gusset Dyke; 850 yards south of Holme Woods and one mile south of Holme.
11. Hingcliff Scar, 650 yards south-east of Swinden Lodge; alongside the Porter or Little Don River and about one and a half miles west of Langsett.
12. In Shaw Clough, one mile north-east of Barrow on Midhope Moors; and one mile south of Upper Midhope village.
13. North bank of Calf Knoll Brook, 60 yards west of junction with Thickwoods Brook, and about half a mile south-west of Upper Midhope.

The Range of *Gastrioceras*

Within the area of the present one-inch map all the marine horizons occurring above the top of the Huddersfield White Rock or the uppermost member of the Middle Grit Series, are characterized by various species of the genus *Gastrioceras*, which become the dominant members of the fauna. There is a somewhat abrupt break at the top of the Middle Grit Series. Thus the various mutations of *Reticuloceras reticulatum* which are distinctive of the Middle Grit Series suddenly die out and are only represented by very occasional specimens of *Reticuloceras reticulatum*, mut. γ (or *superbilingue*) in the basal layers of the lowest subzone of *Gastrioceras* characterized by *Gastrioceras cancellatum* Bisat.

An isolated specimen of *Anthracoceras arcuatilobatum* (Ludwig) has been obtained from the roof-shales of the Halifax Hard Bed Coal at Honley (see page 157), though the Coal Measures in which the genus *Anthracoceras* becomes dominant[1] are unrepresented within the present area.

The genus *Gastrioceras* is first represented in the Upper Carboniferous rocks by isolated forms which occur in the marine band characterized by *Reticuloceras reticulatum*, mut. γ. These include *Gastrioceras lineatum* W. B. Wright, and the form doubtfully referred to the same genus by Dr. Wright, and described by him as *Gastrioceras ? sigma*.[2] Between the two genera *Gastrioceras* and *Reticuloceras* there is, however, a close relationship. A distinguishing feature of *Gastrioceras* is the marked development of ribs or tubercles on the sides of the broad umbilicus, while there is also a second lateral lobe in the suture-line. The several species of *Gastrioceras* successively appearing in the Upper Millstone Grits and Lower Coal Measures would appear to constitute an evolutionary series, though not necessarily in a line of simple descent. The following species occur in the Lower Coal Measures and the upper Millstone Grit above the Huddersfield White Rock, and appear to attain their maximum development in the following order:—*Gastrioceras cancellatum* Bisat; *G. crencellatum* Bisat, *G. crenulatum* Bisat, *G. cumbriense* Bisat; *G. subcrenatum* (Schloth.); and finally the associated species *G. listeri* (Martin), *G. circumnodosum* Foord, and *G. coronatum* Foord and Crick. The first named is the dominant form in the marine band which occurs twenty to thirty feet above the Upper Meltham Coal or the top of the Huddersfield White Rock; while *Gastrioceras crenulatum* and *G. cumbriense* characterize the marine band occurring about one hundred feet higher, or approximately the middle of the thick shale series which intervenes between the top of the Middle Grit Series and the Rough Rock.

[1] Bisat, W. S., 'On the Goniatite and Nautiloid Fauna of the Middle Coal Measures of England and Wales,' 'Summary of Progress' for 1929, Part iii (*Mem. Geol. Surv.*), 1930, pp. 75-89.

[2] *Op. cit.*, pp. 196, 197.

Gastrioceras subcrenatum is the characteristic fossil of the marine band overlying the Pot Clay Coal at the base of the Coal Measures, while *Gastrioceras listeri* and allied species are predominant in the roof-shales of the Halifax Hard Bed Coal, or about 250 ft. above the base of the Coal Measures.

The Subzone of Gastrioceras cancellatum.—One of the best known and most readily recognizable marine horizons in the whole of the Millstone Grit Series is that which occurs in the shales overlying the Upper Meltham Coal where present, and elsewhere the top of the Huddersfield White Rock. This band is frequently referred to as the Meltham Marine Band, and it is clearly the local representative of the Holcombe Brook Marine Band of East Lancashire.[1] The marine band usually occurs about twenty to thirty feet above the Upper Meltham Coal, or the top of the Huddersfield White Rock. In the intervening shales, *Lingula sp.* and *Modiola sp.* occasionally occur.

The fauna of the marine band includes, in addition to the dominant species *Gastrioceras cancellatum*, a closely related form described by Mr. Bisat as *Gastrioceras cancellatum*, var. *crencellatum*.[2] On Meltham Moor the latter is by far the most abundant fossil on this horizon. *Gastrioceras cumbriense* Bisat, which is the dominant goniatite in the succeeding marine band, has also been found in the *G. cancellatum* marine band at Midhopestones. *Reticuloceras reticulatum*, mut (*superbilingue*) is also recorded from the basal layers of the *G. cancellatum* marine band at the Dolly Folly Waterfall near Meltham Mills, though it has not been found elsewhere. A form which is very similar to *Gastrioceras subcrenatum* (Schloth.) also occurs in the uppermost part of this band at the same locality. Other cephalopods which occur in the Meltham or *G. cancellatum* marine band include: *Dimorphoceras sp.*, *Homoceras divaricatum* (Hind), *Metacoceras sp.*, *Orthoceras* cf. *conquestum* de Koninck, and *Orthoceras sp.* The lamellibranchs are represented by the following species: *Posidoniella multirugata* J. W. Jackson, *Posidonomya insignis* J. W. Jackson and closely related forms; and *Pterinopecten elegans* J. W. Jackson. All these forms are frequent in the *G. cancellatum* marine band, though not wholly confined to that horizon. *Posidoniella multirugata* is common in all the marine zones characterized by species of *Gastrioceras*, while *Pterinopecten elegans* is almost entirely confined to the Cancellatum and Cumbriense subzones. Other fossils recorded from the *G. cancellatum* marine band include the gastropod *Loxonema* cf. *pulcherrimum* M'Coy; ostracods, and fish scales referred to the genus *Palaeoniscus*.

In a water-boring at Brockholes, about one mile to the south of Honley, this marine band has yielded a fragmentary jaw, with some of the teeth attached, of the Elasmobranch fish *Edestus* (see below, p. 157). The boring is on the premises of Messrs. Joseph

[1] 'The Geology of the Rossendale Anticline' (*Mem. Geol. Surv.*), 1927, p. 117.
[2] *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 122.

Sykes and Co. at Rock Mills, alongside the River Holme at Brockholes. The Upper Meltham Coal resting on a hard grey sandstone (Huddersfield White Rock) occurred at a depth of 142 ft. from the surface, and was three inches thick. It was overlain by a dark grey flaggy micaceous shale, crowded with shells which appear to be identical with *Modiola transversa* Hind. The marine band occurred 22 ft. above the coal and yielded in addition to *Edestus* the following shells:—" *Posidoniella laevis* (Brown), *Gastrioceras* sp., *Glyphioceras reticulatum* (Phill.), and *Orthoceras* cf. *asciculare* Brown."[1]

Fossils have been collected from the *G. cancellatum* marine band by the Geological Survey at the following localities within the area of the one-inch map, Sheet 86 (Glossop):—

1. Right bank of stream, just below Dolly Folly Waterfall; and 500 yards north of St. James Church, Meltham Mills.
2. Disused shale-pit, northern slope of Meltham Cop; 200 yards west of Cop Farm, and one mile north of Meltham.
3. Left bank of stream, 1,200 yards west of disused coal shaft; and 1½ miles south-west of Meltham Church.
4. Right bank of stream, 150 yards south-west of White Holes Farm, Deerhill Brow, and 700 yards south of the south-east corner of Deerhill Reservoir, Meltham.
5. On east bank of Knoll Brook, Wind Hill Wood; about three-quarters of a mile south of Midhopestones.
6. Old mine tips, from shales above Simmondley Coal. Close to Dinting Goods Station, south-south-east of Gamesley.
7. Near Hattersley, 350 yds. north-north-west of Hillend.

The Subzone of Gastrioceras crenulatum (*and* G. cumbriense). —The marine band in which *Gastrioceras crenulatum* Bisat and *Gastrioceras cumbriense* Bisat are the distinctive goniatite species is always extremely thin, seldom more than a few inches thick, but it appears to be invariably present wherever a section of the shales on that horizon is exposed. It occurs about one hundred feet above the Upper Meltham Coal or the top of the Huddersfield White Rock, and about midway in the thick shale series intervening between the top of the Middle Grits and the base of the Rough Rock. In addition to *Gastrioceras crenulatum* and *Gastrioceras cumbriense,* a form closely resembling *Gastrioceras? sigma* W. B. Wright has been found in this marine band at Meltham. *Orthoceras* is the other cephalopod commonly occurring on this horizon. The lamellibranchs include the following species: *Aviculopecten* cf. *losseni* (von Koenen), *Posidoniella* cf. *multirugata* J. W. Jackson, *Pterinopecten* cf. *carbonarius* Hind, *Pterinopecten* cf. *elegans* J. W. Jackson, and *Pterinopecten sp.* Other fossils occurring in this marine band are *Trepospira* cf. *radians* (de Koninck) and *Productus sp.* Fossils from this horizon have been collected by the Geological Survey from the following localities within the area of the one-inch map, Sheet 86 (Glossop):—

[1] Pringle, J., in *Quart. Journ. Geol. Soc.*, vol. lxxii for 1916, 1917, p. 6.

1. Right bank of stream, 250 yards west of disused coal shaft, Brow Grains Road, Meltham; and one and a half miles south-west of Meltham Parish Church.
2. Steep bank in stream at Child o' th' Edge, about five furlongs north-west of Upperthong.
3. Left bank of stream, Morton Wood; 440 yards south-west of Hepworth Church.

The Subzone of Gastrioceras subcrenatum.—Throughout the present area the Rough Rock is overlain by a prominent bed of fireclay and a thin coal seam known as the Pot Clay Coal. In the shales above the coal a marine band occurs, and the characteristic fossils include the goniatite *Gastrioceras subcrenatum* (Schloth.) and closely related forms. *Gastrioceras listeri* (Martin), which is a closely related form and characterizes the marine band in the roof-shales of the Halifax Hard Bed Coal, is also recorded from the roof of the Pot Clay Coal. Forms also occur intermediate in character between *Gastrioceras subcrenatum* and *G. listeri*. Other cephalopods which occur in the Pot Clay marine band include *Homoceratoides divaricatum* (Hind), *Orthoceras sp.*, and *Dimorphoceras sp.* The lamellibranchs include *Myalina sp.*, *Posidonomya* cf. *gibsoni* Salter, *Posidonomya* cf. *insignis* J. W. Jackson, *Posidoniella multirugata* J. W. Jackson, *Pterinopecten* cf. *elegans* J. W. Jackson, *Pterinopecten papyraceus* (J. Sow.), and *Pterinopecten sp.* *Posidonomya gibsoni* Salter and *Posidoniella multirugata* J. W. Jackson appear to be confined to the uppermost part of the Millstone Grits and the Lower Coal Measures, or the zones characterized by the several species of the goniatite *Gastrioceras*. *Pterinopecten papyraceus* (J. Sow.), which is a very common shell in the roof-shales of the Halifax Hard Bed Coal, appears to be confined to the horizons of the Pot Clay and Halifax Hard Bed coals. Other fossils occurring in the Pot Clay marine band include ostracods and fragmentary fish-remains.

Fossils from this horizon have been collected by the Geological Survey from the following localities within the area of one-inch map, Sheet 86 (Glossop):—

1. Western side of railway-cutting, Scar End; half a mile south of Brockholes railway station, and one mile south-east of Honley.
2. Left bank of stream crossing Barnside Lane; 50 yards south of lane and 800 yards south-south-east of Hepworth Church.

The Middle Band Coal marine horizon.—The Middle Band Coal is a thin but very persistent seam usually overlain by fine black shales which very frequently contain fragmentary fish-remains. At Honley *Lingula mytiloides* J. Sow. also occurs in this band. The fish-remains obtained here include *Elonichthys sp.* and Palaeoniscid remains. Fossils have been collected by the Geological Survey from this horizon at:—

Northern side of railway-cutting, three hundred yards north of Brockholes railway station, and about a mile south-east of Honley.

The Subzone of Gastrioceras listeri.—The marine band overlying the Halifax Hard Bed Coal is the highest marine horizon in the Coal Measures of the district. The Hard Bed Coal has been extensively mined along the outcrop and consequently large collections of the fossils have been made from the roof-shales. The marine band is usually a dull black shale in which calcareous concretions or bullions occur in great abundance in some areas. In these bullions large uncrushed specimens of goniatites are very common. These have practically all been referred to the closely related species *Gastrioceras listeri* (Martin), *Gastrioceras circumnodosum* Foord (=*G. carbonarium* of English authors), and *Gastrioceras coronatum* Foord and Crick. During the re-survey of one-inch Sheet 86 (Glossop), an extensive suite of fossils was obtained from the roof-shales of the Halifax Hard Bed Coal in the disused ganister quarry, two hundred yards east of Honley railway station. In addition to the above-mentioned forms it also yielded the cephalopods *Anthracoceras arcuatilobatum* (Ludwig) and *Orthoceras sp.* The lamellibranchs include the following species: *Posidoniella* cf. *minor* (Brown), *Posidoniella* cf. *multirugata* J. W. Jackson, *Posidonomya* cf. *insignis* J. W. Jackson, *Posidonomya sp.*, *Pterinopecten papyraceus* (J. Sow.) and *Pterinopecten spp.* The other fossils include *Lingula* cf. *mytiloides* J. Sow. and fragmentary fish-remains comparable with *Elonichthys aitkeni* Traquair.

Fish Remains

Fish-remains occur with comparative frequency in the Upper Carboniferous rocks of this district, though they are almost invariably in a very fragmentary condition, consisting of isolated teeth, scales or spines. In the foregoing account of the several marine horizons, reference has already been made to a number of genera which have been collected during the re-survey of the present area.

The most important discovery, however, was made in material from a water-boring at Rock Mills, Brockholes, near Honley, where a fragmentary jaw with some of the teeth attached of the Elasmobranch fish *Edestus* was found in the *Gastrioceras cancellatum* or Meltham marine band (see page 183). These forms are of rare occurrence, and the one found at Brockholes and now preserved in the Museum of Practical Geology is a hitherto unknown species, to which the name *Edestus newtoni* has been applied by Sir A. S. Woodward (see Plate V).[1]

A considerable number of fragmentary fish-remains were obtained from the vicinity of Pule Hill near Marsden about thirty years ago, and these were described by Dr. E. D. Wellburn of Sowerby Bridge.[2] In his accounts the fossils were stated to

[1] Woodward, A. S., 'On a new species of *Edestus* from the Upper Carboniferous of Yorkshire,' with an Appendix by J. Pringle, *Quart. Journ. Geol. Soc.*, vol. lxxii, for 1916, 1917, pp. 1-6.

[2] Wellburn, E. D., 'On the Fish Fauna of the Pendleside Limestones,' *Proc. Yorks. Geol. Soc.*, vol. xiv, 1902, pp. 465-473; 'A list of the Fossil Fishes of the Carboniferous Rocks of Yorkshire, with their Distribution,' *Proc. Yorks. Geol. Soc.*, vol. xvi, 1907, pp. 198-204.

Explanation of Plate V

Edestus newtoni A. S. Woodward, a remarkable row of elasmobranch fish-teeth collected from a boring in the Millstone Grit, 120 ft. below the surface, at Brockholes, near Huddersfield. M.P.G. No. 28346, presented by E. Crowther, Esq., Managing Director of Messrs. Joseph Sykes and Co.

(*c*) anterior ends of cartilages of jaw; (*s*) median symphysial dentition; (*t*) a detached symphysial tooth; (*o*) scattered Orodont teeth.

[Figs. 1-6 are two-thirds of the natural size, figs. 7-10 are twice the natural size].

Fig. 1. The whole fossil, *w* = worn surface on edge of tooth.

,, 2. Anterior end of symphysial dentition, lower view.

,, 3. Front view of the same.

,, 4. Vertical transverse section of root of third tooth of the same.

,, 5 & 6. Transverse sections of second and eighth teeth of the same.

,, 7. Serrations of the border of the eighth tooth.

,, 8. Left half of an elongated Orodont tooth (*Campodus*), front view.

,, 9. Elevated Orodont tooth (*Campodus*), front view.

,, 9a. ,, ,, ,, ,, , upper view.

,, 10. Elevated Orodont tooth (*Campodus*), back view.

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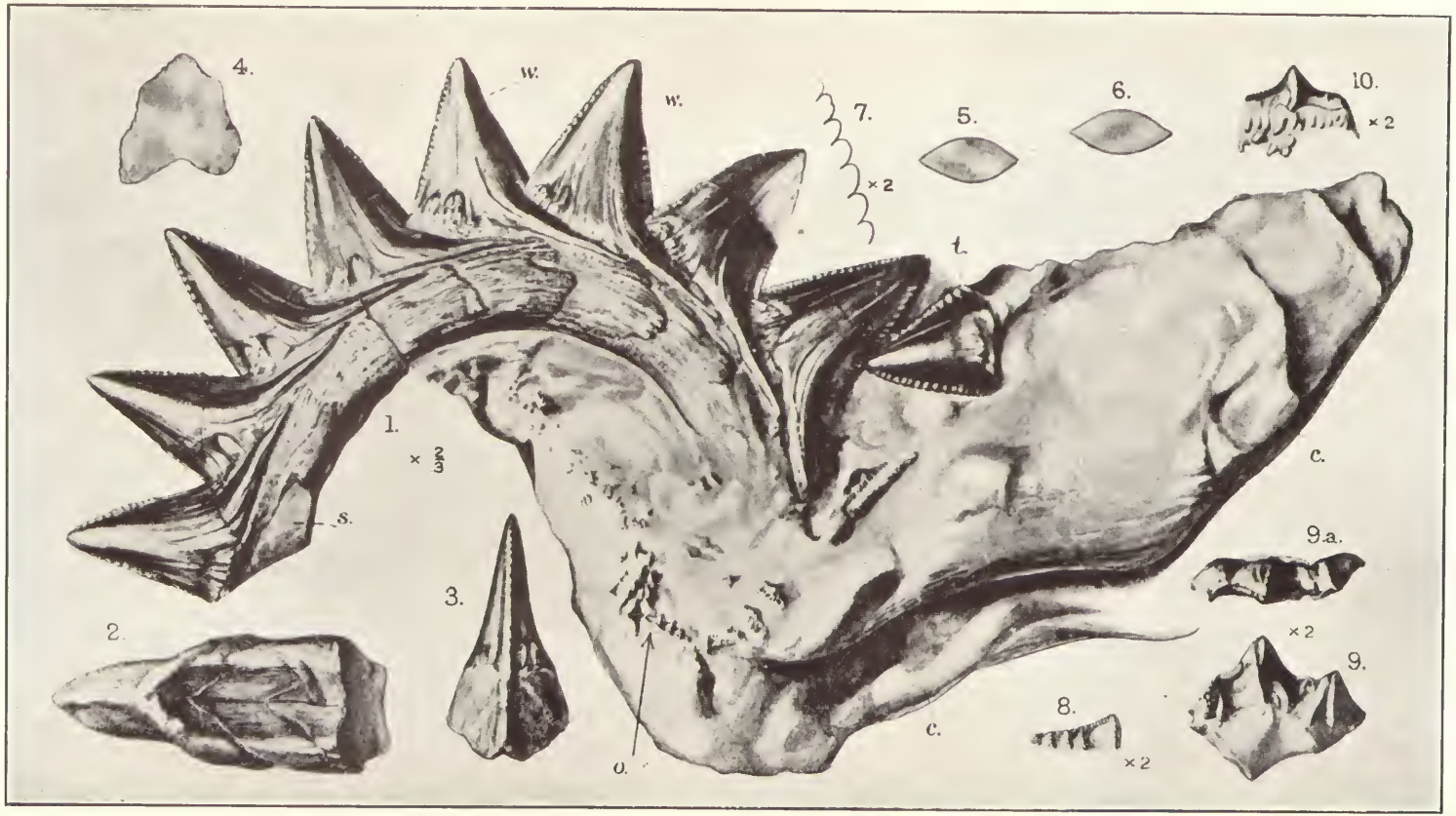

To face p. 158]

EDESTUS NEWTONI. A. S. WOODWARD, FROM BROCKHOLES.

come either from the Pendleside Series or the Middle Grit Shale Series at Pule Hill. It is now known, however, that the rocks of this district formerly referred to the Pendleside Series can no longer be correlated with the strata referred to that group at Pendle Hill, and consequently the name is no longer employed. The whole of the rocks of this area clearly belong to the Millstone Grit Series (see pp. 12, 14), while the shales at Pule Hill everywhere clearly overlie the Kinderscout Grit. Although therefore the exact horizon of these fossils is uncertain, it is clear they came from the shales between the Kinderscout Grit and the lower members of the Middle Grit Series, and within the subzones of *Reticuloceras reticulatum*, mut. α and mut. β.

Among the fossils recorded from Pule Hill was a new genus of Acanthodian shark described by Dr. Wellburn as *Marsdenius*.[1] The complete list of fish-remains from this locality is as follows :— *Acanthodes sp.*, *Marsdenius summiti* Wellb., *Marsdenius acutus* Wellb., *Marsdenius sp.?*, *Rhizodopsis sauroides* Will., *Strepsodus sauroides* Binney, *Elonichthys obliquus* Wellb., *Elonichthys aitkeni* Traquair, *Elonichthys sp.*, *Acrolepis hopkinsi* M'Coy, *Orodus elongatus* Davis, *Ctenacanthus major* Agassiz and *Oracanthus milleri* Agassiz.

During the re-survey of the present area a few fragmentary fish-remains were obtained at several horizons in the Upper Carboniferous rocks, and have been identified by Professor D. M. S. Watson, F.R.S., of University College, London. These have been briefly referred to in the foregoing account of the goniatite zones.

From the Butterly Marine Band in the Kinderscout Grit, Palaeoniscid scales were obtained in the Marsden and Wessenden districts. Similar scales also occur in the mut. α marine band at Marsden. A ridge-scale of *Palaeoniscus* was also obtained from the mut. β band at Heyden Clough.

In the mut. γ band at Wessenden Head and Upperthong there occurred, in addition to Palaeoniscid scales, *Elonichthys aitkeni* and *Coelacanthus sp.*

A few fish-remains were also obtained from the Meltham or *Gastrioceras cancellatum* marine band, including an operculum referred to *Coelacanthus*, and fish scales of three types referred to the genera *Elonichthys* and *Palaeoniscus*.

The fine black shales which overlie the Middle Band Coal are often crowded with fish-remains, though the majority are so fragmentary that they cannot be definitely referred to any specific form. A collection from Honley includes representatives of the genus *Palaeoniscus*. The marine roof of the Halifax Hard Bed Coal has yielded numerous fragmentary fish-remains, including *Elonichthys aitkeni* Traquair.

[1] Wellburn, E. D., *op. cit.*, p. 466.

Other Marine Fossils

In addition to the goniatites characteristic of each of the successive marine bands, other marine fossils occur, and these have been already given under the description of the fauna of each zone. While in the majority of the marine bands cephalopods form the dominant members of the fauna, there are others in which they are almost or completely absent, and it would therefore appear that somewhat different conditions prevailed during the deposition of these marine bands. Thus cephalopods are practically absent from the Butterly Marine Band in the Kinderscout Grit and from the estuarine band in the upper part of the Pule Hill Grit or Heyden Rock, and also from the marine shales which form the roof of the Middle Band Coal.

In those marine horizons characterized by goniatites, the cephalopods are also represented by forms referred to the genera *Dimorphoceras, Homoceras* and *Homoceratoides*.

Dimorphoceras Hyatt is represented in practically all the marine bands by fragmentary forms and impressions, but no detailed study of these forms has yet been made to ascertain whether any of them have any zonal value.

The genus *Homoceras* Hyatt closely resembles *Reticuloceras*, differing, however, from that genus in the absence of ribs in the young forms. *Homoceras proteum*[1] occurs in the bands characterized by the mutations of *Reticuloceras reticulatum*, while *Homoceras striolatum*[2] only occurs in the 'mut. α' marine band overlying the Kinderscout Grit. The genus *Homoceratoides* Bisat is very closely related to both *Homoceras* and *Reticuloceras*. Thus it shows close agreement with *Homoceras* in the character of its adult ornament and with *Reticuloceras* in its earliest ribbing.[3] It is invariably represented in the majority of the marine bands by the one species *Homoceratoides divaricatum* (Hind),[4] and consequently is not of any value for the purposes of zoning.

Marine lamellibranchs, gastropods, brachiopods and crinoid remains occur in practically all the marine bands in the Upper Carboniferous rocks of this district. For the purposes of zoning, the gastropods and brachiopods have not been sufficiently studied, the several species being recorded from widely varying horizons. The marine lamellibranchs *Pterinopecten, Aviculopecten, Posidonomya* and *Posidoniella* have, however, been the subject of a detailed study by Dr. J. W. Jackson, who finds that many of the species have a limited vertical range and can thus be used to supplement the goniatite succession for the purpose of zoning. The principal forms are:—*Posidoniella laevis* (Brown) which is characteristic of the marine band with *Reticuloceras reticulatum*,

[1] Brown, T., *Trans. Manch. Geol. Soc.*, 1841, p. 217.
[2] Phillips, J., 'Geology of Yorkshire: Part ii, The Mountain Limestone District,' 1836, p. 234 and plate xix, figs. 14-19.
[3] For full description see W. S. Bisat, 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1924, p. 112.
[4] Hind, W., *Geol. Mag.*, 1918, p. 448.

mut. β ; *Posidoniella minor* (Brown) common in the mut. α marine band; *Posidoniella multirugata* J. W. Jackson, characteristic of the marine bands yielding species of *Gastrioceras,* namely, *G. cancellatum, G. cumbriense, G. subcrenatum* and *G. listeri*; *Posidoniella rugata* J. W. Jackson, confined to the marine bands close above the Kinderscout Grit, namely those of *Reticuloceras reticulatum,* mut. α and early mut. β ; *Posidonomya gibsoni* Salter, apparently confined to the roof of the Halifax Hard Bed Coal; *Posidonomya insignis* J. W. Jackson, frequent in the subzones of *Gastrioceras cancellatum* and *Gastrioceras cumbriense,* but also known from lower horizons as well. *Pterinopecten elegans* J. W. Jackson appears to have a very similar vertical range.

Pterinopecten papyraceus (J. Sowerby) appears to be confined to the lower part of the Lower Coal Measures. *Pterinopecten speciosus* J. W. Jackson is characteristic of the marine bands occurring in the shales between the Kinderscout and Pule Hill Grits.

In the investigation and naming of the fossils in the Millstone Grits from this district, Dr. Stubblefield has observed the occurrence of an undescribed *Aviculopecten,* referred to in our lists provisionally as *Aviculopecten* cf. *losseni* (von Koenen). This form occurs in the subzone of *Gastrioceras crenulatum* and *G. cumbriense* at Meltham and near Ewden and also along with *Gastrioceras* cf. *cumbriense* in material from apparently corresponding horizons in Breconshire, South Wales. The association of this new species of *Aviculopecten* with the fauna of the *Gastrioceras cumbriense* subzone has already been noticed in Lancashire and Cumberland by Dr. J. W. Jackson.[1]

Non-marine Lamellibranchs

Among the commonest fossils which occur in the Coal Measures are the Mollusca referable to the genera *Carbonicola, Anthracomya* and *Naiadites.* The remains of these shells are never found in the same beds as the remains of marine organisms such as goniatites, brachiopods or lamellibranchs referable to the genus *Pterinopecten,* and are generally considered to be of estuarine or freshwater origin. In some cases, such as that of the Pot Clay Coal at the base of the Coal Measures, the overlying shales contain bands with both non-marine and marine fossils. The two beds are, however, quite distinct and no commingling of the two faunas is known to occur.

The non-marine lamellibranchs are first definitely known in the Middle Grit Series; they only occur, however, at very occasional horizons in the Millstone Grits and become more frequent in the lower part of the Coal Measures. In the Middle Coal Measures they are comparatively abundant, and *Carbonicola* bands, as they are termed, occur in one place or another in the shales above the majority of the principal coal seams.

[1] 'Problems in the Classification of the Carboniferous Rocks,' Presidential Address, *Journ. Manch. Geol. Assoc.*, vol. i, pt. 2, 1929, p. 72.

It was not until the late Dr. Wheelton Hind published his important monograph on the genera *Carbonicola, Anthracomya* and *Naiadites* in 1896,[1] that any attempt was made to employ these forms for the purpose of zoning and correlating the Coal Measures. Wheelton Hind showed the value of various species in the identification of numerous horizons, and indicated in a very general way a zonal system more particularly applicable to North Staffordshire. Within recent years, however, these non-marine lamellibranchs have been the subject of more detailed investigations by numerous workers, and mainly under the guidance of Professor A. E. Trueman, a zonal system, originally established by that writer and Mr. J. H. Davies in South Wales,[2] has been extended to the majority of the British coalfields. The Coal Measures of the Holmfirth district (as included within the limits of Sheet 86) fall within three of the main zones as established by these geologists, which in ascending order are as follows:—(1) The Zone of *Anthracomya lenisulcata,* extending from the base of the Coal Measures to the top of the Elland Flags or Greenmoor Rock; (2) the Zone of *Carbonicola ovalis,* including the measures between the Elland Flags and the New Hards, Swilley or Middleton Main Coal; and (3) the Zone of *Anthracomya modiolaris,* including all the higher measures.[3]

The Millstone Grits.—Few horizons are known at which non-marine lamellibranchs occur in the Millstone Grits, and of these two are at present known only from the materials obtained in a deep boring at Oxspring, near Penistone.[4] The lowest occurred in the Millstone Grit Series at a depth of 530 feet below the base of the Coal Measures. This was a band of black shale below the Huddersfield White Rock which yielded *Anthracomya minima* (Ludwig). It occurred 32 feet above the marine band characterized by *Reticuloceras reticulatum,* mut. ~ (*superbilingue*) Bisat.

The second or higher horizon at Oxspring occurs at the top of the Middle Grit Series and about 15 feet above the Upper Meltham Coal; it immediately underlies the *Gastrioceras cancellatum* marine band. The fauna includes *Carbonicola ornata* Trueman, *C. pseudacuta* Trueman and *Naiadites producta* (Brown). The two species of *Carbonicola* appear to be confined to, and characteristic of, this horizon.

The only other horizon at which non-marine lamellibranchs have been found in the Millstone Grits Series is in shales 24 ft. below the base of the Rough Rock at Langsett, near Penistone.

[1] Hind, W., 'A Monograph on *Carbonicola, Anthracomya* and *Naiadites*,' *Palaeont. Soc.*, 1894-96.

[2] Davies, J. H., and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures, and a Discussion of Their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxv, 1929, p. 210.

[3] For full details see D. A. Wray and A. E. Trueman, 'The Non-Marine Lamellibranchs of the Upper Carboniferous of Yorkshire and their Zonal Sequence,' in 'Summary of Progress' for 1930, Part iii (*Mem. Geol. Surv.*), 1931, pp. 70-92.

[4] The site is on the bank of the River Don about 2 miles S.E. of Penistone, just outside the area shown on the map.

Here in a shale cliff alongside Midhope Reservoir numerous impressions of *Carbonicola* occur, including forms closely allied to *Carbonicola recta* Trueman,[1] a very distinctive species of the lowest part of the Coal Measures.

The Coal Measures.—In the lowest zone of *Anthracomya lenisulcata* are included about 750 ft. of measures extending to the top of the Greenmoor Rock. In addition to the index-fossil *Anthracomya lenisulcata* Trueman, other characteristic fossils include *Anthracomya prisca* Trueman, and some closely related forms.

1. The Pot Clay Coal.—The thin coal seam which forms the base of the Coal Measures and rests upon the Rough Rock is succeeded by a marine band (see p. 78), though in many places a ' mussel ' band has been found to intervene between the coal and the marine band. The fossils from this band include the zone fossil *Anthracomya lenisulcata* and closely related forms. In the boring at Oxspring a band with *Anthracomya* was found about 70 ft. above the Pot Clay Coal. This band yielded *Anthracomya prisca* Trueman, and indeterminate forms of *Carbonicola*. *A. prisca* appears to be of considerable value as a zonal fossil, for it is distinctive of, and apparently confined to, the lowest 250 ft. of the Coal Measures.

2. The Soft Bed Coal.—The wide occurrence of a band with non-marine lamellibranchs in the measures a short way above the Soft Bed Coal has long been known. The commonest fossils include *Carbonicola pseudorobusta* Trueman and *C. recta* Trueman. There are, however, wide variations in the forms referred to these two species, and it is possible several distinct though allied species may be represented. A form closely related to *Carbonicola ovalis* (Martin) has been found on this horizon in the Oxspring boring, while *Anthracomya minima* (Ludwig) and *Anthracomya* cf. *bellula* Bolton also occur in this band above the Soft Bed Coal at Honley.

3. The measures above the Hard Bed Coal.—At Langsett, near Penistone, a well-marked molluscan band with *Anthracomya* occurs in the shales 50 to 70 ft. above the Hard Bed Coal. *Anthracomya prisca* and *A. lenisulcata* are the commonest shells at this horizon. In the boring at Oxspring the same band was also met with and, in addition to the two above-mentioned species of *Anthracomya*, yielded *Beyrichia sp.*

4. The Whinmoor Coal.—Within the area of the present one-inch map no bands with non-marine lamellibranchs have been observed in the thick series of measures extending from about 70 ft. above the Halifax Hard Bed Coal to the Whinmoor Coal. In the country to the north, however, numerous bands occur in the measures overlying the Elland Flags (or Greenmoor Rock).

[1] A full account of the diagnostic characters of these Millstone Grit Mollusca is given by A. E. Trueman in ' Some new Carboniferous Lamellibranchs,' *Annals and Mag. Nat. Hist.*, Ser. 10, vol. iv, 1929, p. 82.

Around Huddersfield the Better Bed Coal rests directly on the upper surface of the Elland Flags and forms a suitable datum line, being provisionally taken as the boundary between the Zones of *Anthracomya lenisulcata* and *Carbonicola ovalis*.[1] Farther north, however, at Brighouse a series of shales intervene between the topmost bed of the Elland Flags and the Better Bed Coal, and have yielded a fauna characteristic of the *Carbonicola ovalis* Zone, including many large species such as *Carbonicola ovalis* (Martin), *Carbonicola communis* Davies and Trueman and *Carbonicola* cf. *subconstricta* (J. Sowerby).[2] What is believed to be the corresponding band has also been recognized with a similar fauna in the Leeds district.[3] The top of the Elland Flags is, therefore, now taken as the base of the Ovalis Zone.

The Whinmoor Coal occurs about 400 ft. above the level of the Better Bed Coal or the top of the Greenmoor Rock. In the shales overlying this seam at Scissett a band rich in casts and impressions of non-marine lamellibranchs occurs, and its fauna is very characteristic of the Ovalis Zone. The genus *Carbonicola* is represented by several species, including forms closely allied to *Carbonicola ovalis, C. communis, C. subconstricta* (J. Sowerby), *C. agrestis* (Brown) and *C. pseudorobusta* Trueman. A notable feature of this band is the great abundance of *Naiadites,* forms closely related to *N. triangularis* (J. de C. Sowerby) being especially common.

5. The Wheatley Lime Coal.—The roof of the Wheatley Lime or Silkstone Four Foot very frequently has a ' mussel ' band above it, and yields a fairly characteristic assemblage of shell species. Ostracods and *Spirorbis* also frequently occur in this band.

Fossils have been collected from the roof-shales of this coal at a crop-working alongside Bilham Shrogg, Clayton West, and include *Carbonicola decorata* Trueman, *Carbonicola* cf. *subconstricta* (J. Sowerby), *Carbonicola* cf. *rhomboidalis* Hind and several species closely allied to *Carbonicola communis* Davies and Trueman. *Carbonicola decorata* is a large radially-striated shell with the general shape of *Carbonicola pseudorobusta* Trueman.[4] This species appears to be confined to the horizon of the Wheatley Lime and New Hards coals and consequently should prove of some value as a zonal fossil.

From the roof of the Wheatley Lime Coal at the Park Mill Collieries a large collection of shells was obtained. This included a considerable proportion of examples of *Carbonicola ovalis* (Martin) and *Carbonicola communis* Davies and Trueman, associated with less abundant specimens very closely related to *Carbonicola obtusa* Hind and *Carbonicola binneyi* W. B. Wright.

[1] Wray, D. A., and A. E. Trueman, *op. cit.*, p. 74.

[2] Walton, J., ' Non-marine Lamellibranchs between the Better Bed Coal and the Elland Flags,' *The Naturalist*, 1932, p. 121.

[3] Edwards, Wilfrid, ' The Geological Structure of Leeds,' *Trans. Leeds. Geol. Assoc.*, vol. v, 1930-31, p. 6.

[4] Trueman, A. E., ' Some new Carboniferous Lamellibranchs,' *Annals and Mag. Nat. Hist.*, Ser. 10, vol. iv, 1929, pp. 89, 90 and text-fig.

The latter, however, is more elongate than the holotype of that species as described by Dr. Wright.[1] Other shells include forms closely related to *Carbonicola os-lancis* W. B. Wright, while *Naiadites* is represented by *Naiadites* cf. *triangularis* (J. de C. Sowerby).

At the level of the next succeeding coal seam, the New Hards or Swilley, there appears to be a distinct palaeontological break, and this is, therefore, taken as marking the dividing line between the Zones of *Carbonicola ovalis* and *Anthracomya modiolaris*. The latter zone (briefly referred to as the Modiolaris Zone) includes all the measures from the level of the New Hards to that of the Barnsley or Gawthorpe Coal. The zonal fossil, which is characteristic of the corresponding measures in South Wales, appears, however, to be comparatively rare in Yorkshire. The genus *Anthracomya,* in fact, is only poorly represented throughout this zone in Yorkshire. The several species of *Naiadites* which occur at various horizons belong to forms also found in the Ovalis Zone. The genus *Carbonicola* is represented in the lower part of the Modiolaris Zone by forms such as *Carbonicola communis, Carbonicola pseudorobusta* and related species which range up from the preceding zone, though in addition there are numerous small, generally stout and inflated forms closely related to *Carbonicola turgida* (Brown), *C. venusta* Davies and Trueman, *C. exigua* Davies and Trueman and *C. affinis* Davies and Trueman, which characterize the lower measures.

6. The New Hards Coal.—The roof-shales of this seam frequently yield numerous casts and impressions of non-marine lamellibranchs. An extensive collection has been made from this horizon at the Park Mill Collieries, Clayton West, and this includes *Carbonicola communis* Davies and Trueman, *C. ovalis* (Martin), *C. pseudorobusta* Trueman, *C.* cf. *rhomboidalis* Hind, *C.* cf. *rhindi* (Brown), *C.* cf. *boltoni* W. B. Wright and *C. os-lancis* W. B. Wright. The latter is one of the commonest species, and appears to be a very characteristic shell of the lower part of the Modiolaris Zone. An *Anthracomya* of somewhat unusual form has also been obtained on this horizon at the Park Mill Collieries.[2]

From the roof-shales of the Green Lane and Parkgate coals, no non-marine lamellibranchs have been obtained within the present area, though in adjacent areas they yield a fauna distinctive of the lower part of the Modiolaris Zone.

7. The Flockton Coals, Tankersley Ironstone and associated Measures.—The very frequent occurrence of non-marine lamellibranchs in the Flockton group of measures has long been recognized, and their occurrence has, in fact, often been taken

[1] Wright, W. B., 'Additions to the Fauna of the Lancashire Coal Measures,' *Mem. and Proc. Manchester Lit. and Phil. Soc.*, vol. lxxiv, 1930, pp. 48-49.

[2] Wray, D. A., and A. E. Trueman, 'The Non-marine Lamellibranchs of the Upper Carboniferous of Yorkshire and their Zonal Sequence,' in 'Summary of Progress' for 1930, Part iii (*Mem. Geol. Surv.*), 1931, p. 79, and Fig. 2.

as a characteristic feature of this horizon. The Tankersley Ironstone, which occurs usually a few feet above the Flockton Thick Coal and is a mass of *Carbonicola* shells largely mineralized by the carbonates of lime and iron, forms a very distinctive horizon.

The most characteristic shell in the Flockton group of measures is *Carbonicola regularis* Trueman.[1] Some of the larger examples of this shell are practically indistinguishable from *Carbonicola rhomboidalis* Hind. *Carbonicola regularis*, while especially characteristic of the Flockton measures, occurs less frequently in the overlying Haigh Moor measures and is not known from higher measures. Consequently it is of considerable value for zonal purposes. Other fossils which occur in the Flockton group of measures, including the Tankersley Ironstone, are *Carbonicola communis* Davies and Trueman, *C. obtusa* Hind, *C.* cf. *aquilina* (J. de C. Sow.) and *Carbonicola concinna* W. B. Wright. *Naiadites* is represented by *Naiadites* cf. *producta* (Brown) and *Naiadites* cf. *triangularis* (J. de C. Sow.).

Fossil Plants

Plant impressions occur at many horizons in the Upper Carboniferous rocks of this district, though up to the present no systematic collection has been made from any localities within the area of the present one-inch map. Although plant impressions are known from the Millstone Grits, they are far more abundant in the Coal Measures and particularly frequent in the Middle Coal Measures. In the descriptions of some of the commoner Coal Measure plants the localities are occasionally given vaguely as the 'Mines or Collieries in Yorkshire,' and it is not improbable that many of these may have come from localities within the present area. Included within these are the very common species *Neuropteris heterophylla* Brongn. and *Urnatopteris tenella* (Brongn.).

Forty years ago Dr. Kidston drew up an extensive list of the Coal Measure flora of Yorkshire, which was published by the Yorkshire Naturalists' Union.[2] The majority of these records, together with additional ones, were given also by the same author in his monograph on Coal Measure plants published by the Geological Survey between the years 1923 and 1926.[3] In these publications there appear to be only two authentic records of plant species from places within the area shown on the one-inch map, Sheet 86. These include the occurrence of *Lepidodendron aculeatum* Sternb., from Upper Mill near Holmfirth,[4] and

[1] Trueman, A. E., 'Some new Carboniferous Lamellibranchs,' *Annals and Mag. Nat. Hist.*, Ser. 10, vol. iv, 1929, pp. 90-93.

[2] *Trans. Yorks. Nat. Union*, 1st Report, pt. xiv, 1890, pp. 1-64; 2nd Report, pt. xviii, 1893, pp. 65-82; 3rd Report, *ibid.*, pp. 83-96; 4th Report (with index to 1, 2, 3, and 4), *ibid.*, pp. 97-127; 5th Report, pt. xix, 1896, pp. 129-144; 5th Report (concluded), pt. xx, 1898, pp. 145, 146; 6th Report, pt. xxi, 1898, pp. 147-176.

[3] Kidston, R., 'Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv.*, Palaeontology), vol. ii, 1923-6.

[4] Kidston, R., *Trans. Yorks. Nat. Union*, 1890, Part xiv, p. 47.

Crossotheca hoeninghausi Brongniart, from the Bullhouse Colliery near Penistone.[1] Both of these came from the Lower Coal Measures and almost certainly on or close to the horizon of the Halifax Hard Bed Coal.

These isolated records have little or no stratigraphical importance, and in the absence of further records it is impracticable to draw any conclusions from the flora of the measures exposed within the area of the present one-inch map.

One of the most distinctive botanical features of the Coal Measures is the occurrence of ' coal-balls ' in the Halifax Hard Bed Coal. These are calcareous concretions found in the seam of coal, in which the remains of plants are well preserved, the detailed structures being petrified and so escaping destruction or serious distortion; they have therefore added immensely to our knowledge of the structure of primitive plants and provided valuable evolutionary data. The ' coal-balls ' of Yorkshire have been studied by a British Association committee whose work is summarized in the Annual Reports for 1882 and 1883. Although ' coal-balls ' are known to occur in the Halifax Hard Bed Coal in the Holmfirth district, it was pointed out in the first of the above reports that the Halifax district is the only one from which satisfactory specimens were obtainable; those from other areas being so pyritous that the plant structures were no longer recognizable.

[1] Kidston, R., ' Fossil Plants of the Carboniferous Rocks of Great Britain ' (*Mem. Geol. Surv.*, Palaeontology) vol. ii, Part 4, 1923, p. 335.

CHAPTER VIII

ECONOMIC GEOLOGY

Water Supply

The area shown on the Holmfirth and Glossop Sheet of the one-inch map consists largely of moorland of high elevation, with a rainfall of over 60 inches; this moorland area is sparsely populated, but it is nearly surrounded by areas of dense population. To the west, and to some extent invading the area along the Tame valley, lies the industrial region of Lancashire; to the north the woollen district of West Yorkshire, including such important towns as Huddersfield, Dewsbury and Batley; to the east and south-east the South Yorkshire Coalfield with Barnsley and Sheffield. As a consequence of this distribution local supplies of water depending directly on the geology are of less importance than the impounding of surface supplies for conveyance to towns lying outside the area. The latter is controlled mainly by the physical geography, and only secondarily by the geology.

The greater part of the water entering the reservoirs is direct run-off from the moors; the peat, acting as a sponge, tends to check the sudden rush of flood water at times of heavy rainfall and maintains a flow during dry weather. Fine peaty debris together with sand is removed in settling tanks immediately above the reservoirs, though there is always a certain amount of material carried over, which forms a deltaic deposit in them wherever a stream enters.

The water is pure and soft, but contains peaty acids, which may be a source of danger when passing through lead pipes for domestic supply, unless it is treated with lime to neutralize the acid. Lack of lime in the water has been blamed as a partial cause of the prevalence of rickets. Springs arising from different members of the Millstone Grits also feed the streams; a considerable number are somewhat chalybeate.

The largest series of reservoirs is that stretching for a distance of over five miles along Longdendale, belonging to the Manchester Corporation. Glossop is supplied from reservoirs in the hills surrounding the town, as for instance near Blackshaw. To the north the Swineshaw and Greenfield valleys supply Ashton-under-Lyne, Stalybridge and Dukinfield, which are united for the purpose, while the moorland reservoirs near Denshaw and Castle Shaw belong to the Oldham Corporation; those near Standedge feed the summit level of the Huddersfield Canal, which passes through a tunnel from Marsden to Diggle close to that of the railway.

Huddersfield Corporation derives part of its supply from reservoirs in the valley from Wessenden to Marsden and at Blackmoor Foot west of South Crosland; at both the natural supply has recently been increased by borings. In the Holme valley the waters of Marsden and Hey cloughs are impounded at Bilberry Reservoir, belonging to the Holme Water Works; this reservoir is notorious as the cause of a terrible flood in 1852, "when the embankment gave way, there were not less than 86,248,000 gallons of water in it, or the enormous and fearful amount of 300,000 tons in weight."[1] Of more importance is the series of four reservoirs south of Holmbridge belonging to Batley; the latest and lowest of these was under construction at the time of the re-survey (p. 39), but is now complete and has a capacity of about 265 million gallons.

Dewsbury and Heckmondwike own the five reservoirs which take the headwaters of the Don near Dunford Bridge, and also the higher (more westerly) of the two near Ingbirchworth; Barnsley has the lower of these and also Midhope, between Upper Midhope and Midhopestones; Sheffield those in the main valley of the Little Don near Langsett and others not shown on the map; Langsett Reservoir has a capacity of 1,400 million gallons.

The River Derwent and its tributaries supply the Derwent Valley Water Board, the upper part of the Howden Reservoir being shown within the boundary of the map; the Board supplies water to Sheffield, Nottingham and Leicester, as well as a large part of Derbyshire.[2]

From the above lists it will be seen that practically the whole of the gathering-ground available within the area is being utilized.

Local supplies can be obtained by boring to the various sandstones and grits in the Millstone Grits and in the Lower Coal Measures. Where deep cuttings have been made in the shales, as for instance in the construction of reservoir dams, large amounts of water have sometimes been met with; in the sandstones the main flows are usually along the vertical joints, but in the shales along the bedding-planes; thus at Langsett Reservoir in the shales below the Rough Rock a flow of 40,000 gallons per hour was interrupted and continued to flow for several months practically unabated; the flow was from the undisturbed shales, not from the contorted and crushed material in the valley bottom (p. 129).[3]

In the northern part of the district the Rough Rock is unusually dense and free from joints, a peculiarity which adds to its value as a building stone (p. 72), but renders it practically useless as a source of water supply.

The quality of the water from the Millstone Grits is usually good: the hardness is not seldom below 3 degrees, in which case the water is satisfactory for all purposes; if not above 4 degrees it can be used in the manufacture of fine textiles such as are made around Huddersfield; the Colne valley goods are of a coarser type,

[1] Hobkirk, C. P., 'Huddersfield, its History and Natural History,' 2nd Ed., 1868, p. 154.
[2] See 'Wells and Springs of Derbyshire' (*Mem. Geol. Surv.*), 1929, pp. 37 *et seq.*
[3] Watts, W., Presidential Address, *Trans. Brit. Assoc. Waterworks Eng.*, vol. iv, 1899, p. 13.

and water with a hardness up to 6 or 7 degrees can be used. Around Huddersfield especially the Millstone Grits water often contains a considerable amount of sodium carbonate which reduces the hardness below the figure which the amount of calcium carbonate present in the rocks might be expected to produce. The water from the Brockholes boring (p. 183) had the following analysis :—

	Grains per gallon
Calcium carbonate	0.47
Silica	0.56
Magnesium carbonate	0.36
Sodium carbonate	38.92
Sodium chloride	4.74
Sodium sulphate	0.18

The water from the Coal Measures is often exceedingly hard and unfit for anything except cooling purposes; that from the sandstones in the higher part of the Lower Coal Measures is better and can be obtained in fair quantity at shallow depths where there is a favourable gathering-ground.

In the valleys to the west supplies of water are obtained from the Kinderscout and Shale Grits by boring; at Greenfield, Upper Mill, Dob Cross and Delph the borings are mostly from 150 to 250 ft. deep; at Greenfield a boring to 286 ft. 8 in. yielded six to seven thousand gallons per hour, overflowing at the surface, the diameter at the bottom being 8 in. Oldham Corporation have wells 24 in. in diameter, each 800 ft. deep, at Delph and Linfitts. In the Marsden area also some of the mills have borings to the Kinderscout Grit.

At Brow Grains Reservoir, between Marsden and Meltham, a shaft was sunk down to the base of the Beacon Hill Flags; the upper part of these consisted of hard ganister rock, but headings driven from the bottom of the shaft in the lower part of the Flags yielded a copious supply of soft water. Similarly, alongside Blackmoorfoot Reservoir north of Meltham a fairly abundant supply was obtained by sinking a shaft and driving headings at the base of the Huddersfield White Rock; in all about 364 ft. of headings was driven, the yield being about 200,000 gallons per day; in sinking the shaft a flow of gas was encountered, with the following percentage composition :—

Carbon dioxide	01.10
Carbon monoxide	00.25
Methane...	36.90
Oxygen	12.35
Nitrogen	49.40
	100.00

A borehole for the Meltham Urban District Council, situated on the edge of the moors about one mile south of the town, yields 1,000 gallons per hour from a depth of 196 ft.; another for the Holmfirth Council on the south side of the main road opposite Harden Green Plantation obtains 6,000 gallons per hour from

the Huddersfield White Rock; the top of the rock was reached at a depth of 14 ft. 5 in. and the base at 71 ft. (p. 66).

At Honley and Brockholes fair supplies have been obtained from the Beacon Hill Flags and Huddersfield White Rock respectively; the sections are given in the Appendix (pp. 182-3); at Brockholes, where the specimen of *Edestus* (p. 157 and Plate V) was found, the White Rock was met with at about 145 ft.[1]

East of the escarpment of Lower Coal Measures most local supplies of water are derived from sandstones within that series; an exception is at Skelmanthorpe, where, the supply from a comparatively shallow sinking into the Penistone Flags proving insufficient, a boring has recently been put down to the Rough Rock (see Appendix I, pp. 185, 186).

South of Farnley Tyas the Grenoside Sandstone and Greenmoor Rock show fair yields of water. The Denby and Cumberworth Urban District Council have recently sunk five shallow wells in the former on Low Common; they vary in depth from 17 to 63 ft. The Brewery at Lane Head is supplied by headings tapping both rocks; the total length is slightly over one mile. Near Penistone Station a boring 418 ft. deep, 14 in. in diameter, draws 9,000 gallons per hour from these measures, while the District Council have a 300-ft. boring on Penistone Common south of the town.

At Skelmanthorpe several borings have been carried to the Elland Flags. The water from these beds has a temporary hardness of 12 to 13.5 degrees, no permanent hardness, and between 8 and 9 grains of sodium carbonate per gallon.

Coal

Coal is not now produced in any great quantity within the area: the most important seam is the Whinmoor which is worked around Cumberworth and Denby Dale, mostly to supply fuel for use in the factories working the fireclay underlying the Cumberworth Thin Seam, which is utilized for the same purpose when necessarily extracted with the clay. At Exley Gate Colliery the Silkstone Coal is being worked by means of a shaft. Within the small area in the north-east where they are present, the Blocking, New Hards and Old Hards seams have been worked.

The following notes are additional to accounts of each seam given in the stratigraphical chapters above:—

Coal overlying Kinderscout Grit.—There is usually a thin seam of coal above the Kinderscout Grit in this district. In past years this has been worked on a small scale on the western and southern slopes of Pule Hill. It was got for purely local requirements and is not of any great economic value.

[1] *Quart. Journ. Geol. Soc.*, vol. lxxii, for 1916, 1917, p. 6.

Upper Meltham Coal.—There is invariably a coal immediately above the Huddersfield White Rock and this has been worked on a small scale in many places, though it is nowhere being worked at the present time.

There are disused and overgrown workings in this coal along the northern slopes of Shooters Nab, one mile south-east of Marsden.

Similarly numerous old crop-workings occur alongside the eastern slopes of Deer Hill Moor to the west of Meltham. At Brow Grains there are in addition disused shafts sunk to this coal but they do not exceed fifty feet in depth. In the west of the area there is a disused day-eye at Delph. The Upper Meltham Coal has been worked in numerous places around Meltham but none is working at the present time. There is a small faulted inlier of this coal two hundred yards south-west of Meltham Church; this has been mined from a shaft at Mill Moor, 24 ft. deep. There are many disused shafts to the Upper Meltham Coal in Honley Wood about a mile to the east of Meltham, but we were unable to obtain any details. There are also shallow crop-workings in the Upper Meltham Coal six hundreds yards to the north of Meltham.

The Pot Clay Coal.—There is usually a thick bed of fireclay underlying this coal, and although it has been extensively worked in the country to the south it is not at present worked within the area. On the west this seam (the Six-inch Mine) is 10 in. thick at the Thurston Clough Fireclay Mine.

The Soft Bed Coal.—Though seldom exceeding two feet in thickness it is of fair quality, being relatively free from sulphur and a good coking coal. It has been extensively worked in the past along the outcrop and also mined at considerable depths around Thurstonland and Fulstone. At the time of the re-survey a small mine, worked by day-eyes, was active at Sally Wood, east of New Mill. In the south-east this coal is worked by the Stocksbridge Collieries just within our boundary on the north side of the Little Don. It varies from 1 ft. 6 in. to 3 ft. in thickness and is a first class coking coal. The following is the proximate analysis:—fixed carbon 63 per cent., volatile matter 29·05, moisture 0·65, ash 6, sulphur 0·50. The coal is also worked as a coking coal at Hazlehead by Tinker Bros., but the drift belonging to the Hepworth Iron Co. was abandoned in 1928.

The Hard Bed Coal.—The Hard Bed Coal, which averages two feet in thickness, has been extensively worked both along the outcrop and also by mining, mostly for local use as a house coal. It is somewhat inferior to the Soft Bed Coal, being generally sulphurous. The bed of ganister underlying it is worked at the present time at Honley (p. 174). The most important workings are those of the Hepworth Iron Co.; the colliery is marked on the one-inch map one and a half miles south of Hepworth. A large area has been worked out, both shafts and adits being used.

At Bullhouse Collieries, south of the Don and the railway near Ecklands, the coal is worked in conjunction with the ganister and fireclay.

The Black Bed Coal has been mined to the south of Kirkburton and employed for local industrial purposes. Towards Shelley, however, it thins away to a worthless smut.

The Whinmoor Coal.—The Whinmoor Coal has been worked somewhat extensively around Shelley, Skelmanthorpe, Scissett, Lower Cumberworth and Denby Dale. Usually it is in two or more beds (see p. 83). It is, however, only employed for local industrial purposes, and somewhat rarely for local domestic use. Most of the workings are connected with the fireclay works (p. 175) but the coal is not as a rule satisfactory for use in the kilns.

The Blocking Coal.—This seam has been worked around Royd House and also mined at Park Mill Collieries, Clayton West. At Exley Gate Colliery it is worked for gas, house and steam-raising purposes.

The Wheatley Lime Coal—This seam is a fair average house and industrial coal and has been extensively mined at the Park Mill Collieries, Clayton West. It has also been worked along the outcrop to the south of Clayton West.

The New Hards Coal.—This is one of the most valuable seams in the area and has been and is still being extensively mined at the Park Mill Collieries at Clayton West. On the whole it is a good coal with little ash, and is used largely both for domestic and industrial purposes. The outlier at Pool Hill (p. 112) has been worked out.

The Green Lane is a second class coal and has only been worked on a small scale, mainly along the outcrop.

The Old Hards or Parkgate is frequently a good house coal and has been largely worked in the past. On the south side of the Dearne it deteriorates locally and contains numerous dirt partings.

Cheshire and Derbyshire.—A coal, probably the Lower Yard, has been worked from small pits at Mottram. These workings have long been abandoned.

The same coal has been got during coal strikes by outcropping in the neighbourhood of Broadbottom.

The Simmondley Coal, in the Millstone Grits, has been worked from a shaft on the south side of the railway at Gamesley.

Ganister and Fireclay

Ganister is worked in two districts and at two horizons: around Meltham a bed of ganister at or a little above the top of the Beacon Hill Flags in the Millstone Grits is commercially important; at Honley and from Crow Edge south-eastwards to the

valley of the Little Don the better known ganister below the Halifax Hard Bed Coal has been largely worked along the outcrop of the Lower Coal Measures.

The former is usually a typical ganister with siliceous cement, grey in colour, with angular or subangular grains averaging about one tenth of a millimetre in diameter.[1] The quarries working this bed are as follows:—

Whiteley's Quarry is on the moors opposite the Chain Inn, and about one and a half miles east of Marsden off the Marsden-Meltham main road. The ganister rock is a hard siliceous sandstone up to four feet in thickness in places and overlain by fine black shale. It is pale grey in colour and has abundant rootlet impressions; the silica content is 97·45 per cent., ferric oxide 0·59 per cent.[2] The material is sent by road to Meltham.

Holt Head Quarry is a little to the east of the above and near the Globe Inn on the main road from Meltham to Marsden. The ganister rock is exactly similar in character and thickness to that in Whiteley's Quarry; the sample analysed by the Survey showed silica 98·26 per cent., ferric oxide 0·56 per cent.[3]

Banister Edge Quarries are one and a half miles south-west of Meltham. Here the ganister rock constitutes the upper part of the Beacon Hill Flags. This band of ganister rock reaches up to 12 feet in thickness in places, though it is extremely variable. It directly overlies the Lower Meltham Coal which averages nine inches in thickness.

This band of ganister rock appears to have a wide development on the moors to the south of Meltham. It has been proved in numerous places along Royd Edge, and also along the southern slopes of Royd Edge Clough. The ganister rock worked in this area is conveyed by road to the kilns close to Meltham railway station and employed in the manufacture of silica bricks.

The Halifax Hard Bed ganister in the south-east of the area is of the Sheffield type, that is to say a hard blue ganister with flinty fracture, differing considerably in physical properties from that of the Halifax district, which is often more nearly a siliceous clay and does not yield flinty chips when broken; at Honley it is intermediate in character.[4]

The principal workings are as follows:—

The Gwynn Lane workings, wrongly called 'Royd Edge' in the memoir just quoted, are four hundred yards east of Honley railway station. The ganister is obtained in open workings on the site of an old level in the coal above. The ganister rock varies from 1 ft. 10 in. to 3 feet in thickness. Iron salts derived from the old workings in the coal incrust the joints but the stone

[1] 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. vi, 'Refractory Materials: Ganister, etc. (Resources and Geology),' 2nd Ed., 1920, pp. 28, 29.
[2] *Ibid.*, vol. xvi, 'Refractory Materials: Ganister and Silica Rock (Petrography and Chemistry),' 1920, p. 16, no. 4.
[3] *Ibid.*, vol. xvi, p. 16, no. 5.
[4] *Ibid.*, vol. vi, 'Refractory Materials: Ganister, etc. (Resources and Geology),' 2nd Ed., 1920, pp. 15-33.

is free from pyrites. The ganister rock is used in the preparation of silica bricks at Meltham: analysis gave silica 97·59 per cent., ferric oxide 0·37.[1]

At the Hepworth Iron Works the ganisters beneath the Halifax Hard Bed Coal and beneath the Middle Band Coal are both used; the latter is about 4 ft. thick and forms the top of the 'Middle Rock.'[2] The two beds are ground and sold for cupola-lining.

In the south-east the workings within our area are mostly closed down, those now active being situated farther down the valley towards Stocksbridge. At Crow Edge the ganister laid bare in opencast workings of the Hard Bed Coal has been practically worked out. The Bullhouse Collieries recently worked a bed of silica-rock forming the seat-earth of the overlying Hard Bed Band Coal, on the same horizon as the 'Blue Clay' worked in the country to the north around Elland.[3] In the earlier part of the nineteenth century ganister was largely used as a road-stone.

Fireclay has been worked beneath the Pot Clay, Soft Bed, Halifax Hard Bed and Hard Bed Band coals in the lower part and beneath the Cumberworth Thin Coal in the upper part of the Lower Coal Measures. In the former group the mines were all in the area between Hepworth and Hazlehead; they were worked open-cast or by adits, but are mostly abandoned. The Hepworth Iron Co. work the fireclay, up to 3 ft. thick, beneath the Hard Bed Coal and ganister and that between the Middle Band Coal and its ganister; the latter is up to 2 ft. 6 in. thick. The material is used in the kilns in which conduits, pipes and bricks are made (below). At about the same horizon as the Pot Clay the clay below the Six Inch Mine Coal is worked on the western side of the Pennines near Delph Station; it is up to 6 ft. thick, that below the underlying Sand Rock Mine being about 4 ft. 6 in.[4]

The Cumberworth Thin Coal is a thin worthless seam of coal, but rests on a thick bed of fireclay (see page 96). This fireclay is at present being worked along the outcrop at Lower Cumberworth for the manufacture of tiles and various kinds of ware.

In the neighbourhood of Ponker, to the north of Lower Cumberworth, the fireclay averages 4 ft. 6 in. in thickness, and is worked by the Cumberworth Brick, Tile and Fireclay Co. Bromley Works (Naylor Bros., Denby Dale) lie west of the railway and north of the Denby valley; the extensive outcrop along both sides of the East Hill Beck is being actively exploited, the clay being about 4 ft. thick. The same firm also works this clay in the valley of the Flat Wood Dike, just east of

[1] 'Special Reports on Mineral Resources' (*Mem. Geol. Surv.*), vol. xvi, p. 16, no. 6.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 105.
[3] 'Geology of Huddersfield and Halifax' (*Mem. Geol. Surv.*), 1930, p. 179.
[4] See 'Special Reports on Mineral Resources' (*Mem. Geol. Surv.*), vol. xxvii, 'Refractory Materials: Fireclays (Analyses and Physical Tests),' 1924, p. 57, test AY.

the railway and south of Lower Denby; it is 4 ft. thick and is sometimes overlain by 2 ft. 6 in. of ganister. The Whinmoor Coal is got for steam-raising. J. Kitson and Son's works are just east of Denby Dale Station; a recently made adit at Bank Royd shows 3 ft. 1 in. of clay. During the re-survey the Denby Fireclay Co. began to mine this clay in the outlier immediately south of Upper Denby; the thickness proved was 4 ft.

Building Stones, Flagstones, etc.

Massive gritstones, finer sandstones and fissile flagstones are abundant in the district; the first are confined to the Millstone Grits, but sandstones and flagstones are available both in that series and in the Coal Measures. The older buildings throughout the area are constructed of these local materials, which were also used for field walls and for roadstone. In recent years the high cost of quarrying, the facility of transport and other factors have led to an increasing use of brick for buildings, artificial stone for paving and stone brought from a distance or slag for road-making. As a consequence many of the small quarries which supplied stone for use in their immediate neighbourhood, and some of the larger ones, are now standing idle.

The Kinderscout Grit.—These beds afford an unlimited supply of coarse massive stone, which has been largely used for such heavy work as the construction of reservoir dams; there are several large quarries, now standing, along the Standedge main road which were worked for this purpose. For the several reservoirs in the valleys round Holmbridge and Holme Kinderscout Grit was obtained on the spot. Numerous large abandoned quarries in the Tame valley and in Longdendale show that the industry was very big in the days of the industrial development of the western Pennine valleys. The towns and villages are almost entirely built of and paved with Kinderscout Grit. Building stone and setts were found close at hand in the valley sides. The most massive grit was used for engine beds, and was sometimes brought from the moors for this purpose. Flagstone for roofing was more difficult to find. A bed in the middle of the Kinderscout Grit was worked high up on the moors at Glossop Low and on Slatepit Moor.

The few quarries now working raise building stone, setts (for which the demand is diminishing), kerbs, rubble and pitching. There are abundant supplies of stone suitable for paper-mills but they are not at present used in the area.

In the Glossop area the only productive quarry is on Shire Hill, east of the town. The grit is worked for setts and kerbstones; the waste material is crushed and graded for use as sand and gravel.

The Middle Grits.—Practically all the main beds of gritstone have been worked at one time or another, mainly because of ready accessibility.

The Readycon Dean Series affords flagstones, which were formerly much used for roofing. They are still worked at Alison and Bingley quarries between Holmbridge and Bradshaw and were so until recently at Victoria Quarry on the east side of the valley near Hinchliffe Mill.

The Pule Hill Grit is at present being quarried at the Pule Edge Quarries, and employed both for paving stones, setts, and, to a lesser degree, as a building stone. There are also large quarries in this bed of gritstone at Little Nab End, eight hundred yards to the north of Pule Hill. These appear to be worked intermittently.

The Pule Hill Grit is also being worked at Scout Hill to the south-east of Marsden for paving stones and other purposes. There are also large quarries in the Pule Hill Grit at Netherley to the south-west of Marsden, around Hollingworth and in the Tame valley. A quarry in the west side of Mouselow Hill yields a medium to fine-grained sandstone which is used for setts and building stone, while a few of the better lifts provide monumental stone. The overburden at this quarry is large, being from 25 to 30 feet of grey shale.

The Heyden Rock has been largely quarried at Upper Heyden, the name being chosen on account of these exposures; though of sufficient importance to be engraved on the one-inch map, the quarries are abandoned, no doubt on account of the difficulty of access. Woodhouse Quarries, half a mile east-south-east of Holmbridge are worked by J. Marsden and Sons for ashlar, sills, setts, etc., and show about 24 ft. of good stone. The large quarries at Greystone-edge on the line of the Woodhead Tunnel are abandoned.

The Beacon Hill Flags are rarely worked except for purely local purposes. In the country between Marsden and Meltham the upper part consists of ganister rock and is quarried for this material (see page 59).

The Huddersfield White Rock is usually a flaggy sandstone and has been quarried in several places. Thus there is a small group of quarries at Royd Edge to the south-west of Meltham. There is also a large quarry in the same rock known as Woodside Quarries at Thick Hollins to the south-east of Meltham.

The Huddersfield White Rock was formerly quarried at Netherthong and also in the Holme valley to the south-west of Thongsbridge. Kaye Stone Pits, on the north side of the Greenfield road near Bradshaw are worked intermittently for flags; they show about 30 ft. of fine-grained micaceous sandstone.

The most important area for this rock is Cartworth Moor; from near Holmfirth almost to Cook's Study is a succession of quarries, of which the chief are Attorney Croft Wood, Dunsley Nook, Bank Head, Hill House Edge, White House Edge and Catholes. Sawn blocks, sills, flagstones, setts, etc., are produced by a number of firms; about 15 ft. at the base of the bed is the

best stone, a fine-grained, grey, massive sandstone, occasionally spoilt by the presence of 'mare-balls.'

The Rough Rock.—The Rough Rock was formerly somewhat extensively quarried at Shooters Nab, two miles to the west of Meltham, where there are many large quarries all now in disuse. The grit is here thick bedded and massive, and the lowest beds somewhat flaggy. There are also large disused quarries at Crosland Edge and South Crosland.

The Rough Rock is still being quarried at Scotgate Quarries to the west of Honley. Here it has been worked for many years for building stones, kerb stones, window lintels, etc. Considerable quantities have been sent away from time to time to distant centres. York Castle is reputed to be built in part of stone from the Scotgate Quarries. It has also been employed in other public works and buildings in several towns in Yorkshire and Lancashire.

There are also quarries in the Rough Rock at Brockholes, just to the south of the station. The stone here is, however, all employed locally. There are several large quarries in Honley Wood, and these have been reopened from time to time to suit local requirements. Here, however, the rock is somewhat variable in character.

In the south-west the Rough Rock has been quarried at Broadbottom, close to the railway viaduct. It is there a coarse grit and fine conglomerate, with flagstone and sandstone beneath.

East of Holmfirth some small quarries at Paris are being worked on a small scale. Farther south the Hade Edge Quarries are on the western edge of Daisy Lee Moor. On either side of Harden Clough, where the underlying Rough Rock Flags can be separated from the Rough Rock proper (p. 21), almost the whole outcrop of the former has been worked. The famous Magnum Bonum and Snailsden quarries are abandoned, but those at Lower Edge are active and produce good flagstone, etc. The seat-earth of the thin coal which parts the flags from the grit is used by Nayler Bros. of Denby Dale (p. 175) for silica-stone and fireclay. Flagstones and tilestones were formerly sent from this area as far as Manchester.[1] Stone from quarries in the Rough Rock near Langsett was found to be thoroughly satisfactory for use in constructing the reservoirs.

The Greenmoor Rock (or Elland Flags).—The Greenmoor Rock has been described as "perhaps the most beautiful and valuable stone of the Yorkshire Coal Measures."[2] Though this description applies mainly to the neighbourhood of the type-locality south-west of our area, the stone maintains its character, and is largely worked, near the Sovereign Inn half a mile south of Shepley, by Smith, Heywood and Co., Hampson and Co., George Lindley and Sons and smaller firms. The best stone can

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 58.
[2] *Op. cit.*, p. 125.

be obtained in large blocks, the grain is fine and even and the colour a pleasant blue-grey. Some of the lifts are thin bedded and produce good flagstones; other products are sills, mullions and other building requisites, setts, and to a small extent monumental slabs. Farther north the Elland Flagstone type comes in, but the beds have not been worked to any large extent within the area.

The Grenoside Rock has been quarried around Shepley, Kirkburton and Birds Edge. Other sandstones in the Coal Measures, such as the 80 Yards Rock and the Penistone Flags, are worked on a small scale for purely local purposes.

Short Notes

Ironstone.—The Hepworth Iron Company was founded in 1859 and worked the ironstone occurring as nodules and bands in the shales immediately above the Hard Bed Band Coal, here 77 ft. above the Hard Bed. The manufacture of iron continued only for about 10 years, but the name is retained by the present firm who have long been manufacturers of clay, fireclay and ganister goods (see pp. 85 and 175). The slag from the old iron-works was used for the manufacture of slag-wool about the year 1897. Where similar ironstone nodules are found in the course of working the Coal Measure shales for brick-making or other purposes, they are sometimes collected and sold, as opportunity offers, when a sufficient quantity has been accumulated.

The pyritous nodules occurring above the Halifax Hard Bed Coal have in the past been used for making ' green vitriol,' notably at Bullhouse, where the calcareous nodules have also been burnt for lime.[1]

Clays for Brick-making, etc.—Both in the Millstone Grits and in the Lower Coal Measures lime-free shaly mudstones suitable for brick-making are abundant. The Grindslow Shales have been worked in the past north of Delph. The Hepworth Iron Co. produce red and blue bricks, tiles, chimney pots, etc., from the shales immediately below the Hard Bed fireclay; up to twenty feet of these shales, locally known as the ' blue clay ' are available, below which they become nodular and useless. The blue bricks of ' Staffordshire ' type are produced in the hotter parts of the kilns and have been extensively used in the neighbourhood, for instance in construction of the railway viaduct at Crigglestone. The firm's chief speciality, however, is conduit pipes for electric cables, mainly for Post Office use; these are made single, double or treble; conduits with more than three separate channels are not made in single pieces. The Halifax Hard Bed Coal is used for firing and the fireclay for kiln-construction, so that a single excavation supplies all the materials necessary for the industry.

[1] ' Geology of the Yorkshire Coalfield ' (*Mem. Geol. Surv.*), 1878, p. 110.

At Thurstonland a thick mass of shaly mudstone between the upper and lower beds of the Elland Flags has been worked on a large scale, but the pits are now idle.

There are also extensive brick, tile and pipe works at Upper Cumberworth where the shale and mudstones above the Black Band Coal in the Lower Coal Measures are worked for ordinary bricks. The tiles, pipes, etc., are manufactured at these works from the fireclay underlying the Cumberworth Thin Coal (see p. 96).

Sand and Gravel.—In the south-western corner of the area the glacial deposits are utilized as a source of sand and gravel. Shallow pits at Brookfield show sand with lenticles of well-graded gravel, but the presence of rolled fragments of shale is deleterious for many purposes; these pits are mostly idle, but a sand-pit immediately west of Melandra Castle is worked at intervals.

Large quantities of sand and gravel are periodically dug out of the reservoirs in Longdendale and elsewhere.

Peat.—There are vast quantities of peat available on the high ground, some of it easily accessible from main roads; but it is somewhat fibrous and incoherent and only insignificant amounts are used for fuel. During the coal strike of 1926 a certain amount of peat was sent away from Dunford Bridge Station.

APPENDIX I

Records of Borings

1. Wessenden Head, near Isle of Skye Inn.
2. Crossley Mills, Honley.
3. Rock Mills, Brockholes.
4. Skelmanthorpe.

1. Wessenden Head

A boring for water to feed the Huddersfield Corporation Reservoirs in the Wessenden valley, situated 600 yards west of the Isle of Skye Hotel (Inn on the one-inch map). Made by A. D. Brydon, Ltd.; cores examined by the Geological Survey. Height above O.D. 1,525 ft. Six-inch map, Yorkshire 271 N.E.

		Thickness Ft.	In.	Depth Ft.	In.
	Peat	7	0	7	0
	Stony clay	1	0	8	0
Readycon Dean Series 37 ft. +	Broken grey sandstone	32	0	40	0
	Broken shaly sandstone ...	5	0	45	0
	Grey sandy shale	34	0	79	0
(No cores above this depth)	Soft grey shale. The mut. α marine band lies near the bottom. Traces of fireclay on spoil-heap, probably from the coal above the Kinderscout Grit ...	19	0	98	0
Top of Kinder-scout Grit	Broken grit	8	0	106	0
	Grey sandy shale	2	9	108	9
Grit 54 ft.	Broken grit	22	3	131	0
	Coal		1	131	1
	Broken grit	20	11	152	0
Butterly Marine Bed	Dark grey mudstone with *Lingula mytiloides* J. Sow., *Lingula sp. nov.*, *Orbiculoidea* cf. *nitida* (Phillips), *Aviculopecten* cf. *carboniferus* Hind, *non* (Stevens), *Aviculopecten sp.*, *Edmondia* cf. *transversa* Hind, *Edmondia sp.*, *Posidoniella* cf. *minor* (Brown), *Posidoniella* cf. *pyriformis* Hind, *Sanguinolites* cf. *ovalis* Hind, *Sanguinolites* cf. *striato-granulatus* Hind, *Sanguinolites sp.*, *Schizodus* cf. *antiquus* Hind, *Schizodus sp.*, *Bulimorpha flemingi* (Brown), *Bulimorpha* cf. *flemingi* (Brown), *Euphemus sp.*, *Rhabdospira?* cf. *reticulata* (Brown), fish scales	15	0	167	0
Shale 27 ft.	Grey sandy shale	12	0	179	0

		Thickness Ft.	In.	Depth Ft.	In.
Grit 100 ft.	Shaly micaceous sandstone ...	6	0	185	0
	Grey sandy shale with thin sandstone beds	4	0	189	0
	Coarse current-bedded grit with finer grained beds	54	0	243	0
	Coarse massive current-bedded pebbly grit	36	0	279	0
Shale 11 ft.	Hard dark grey shale, micaceous near top. Small iron-pyrites nodules near base. Obscure plant fragments	10	0	289	0
	Bastard fireclay (6 in.) passing down into micaceous banded sandy shale	1	0	290	0
Grit 42 ft.	Massive current-bedded pebbly grit	42	0	332	0
Shale 42 ft. 10 in.	Dark grey micaceous shale ...	8	0	340	0
	Dark grey, wavy-bedded, sandy and micaceous shale with thin partings of shaly sandstone passing down into :—	13	0	353	0
	Hard grey shale, micaceous in some beds	21	6	374	6
	Hard dark shale full of plant-remains, passing down into the underlying grit	0	4	374	10
Grit 115 ft.+	Current-bedded grit, not very coarse, with much mica on planes of current-bedding	7	2	382	0
	Coarse pebbly grit with mica ...	26	0	408	0
	Grit (not examined)	82	0	490	0

2. Crossley Mills, Honley

A boring for water at Allen Thornton and Sons' Mills, Honley, made and communicated by T. Matthews, Ltd., Imperial Iron Works, Pendleton, Manchester. Height above O.D. 355 ft. Six-inch map, Yorkshire 260 S.E.

		Thickness Ft.	In.	Depth Ft.	In.
	Clay and gravel	14	0	14	0
	Blue shale	13	0	27	0
	Black shale	4	0	31	0
	Blue shale	15	0	46	0
[Rough Rock 137 ft. 6 in.]	Grey rock	10	3	56	3
	Millstone Grit	25	9	82	0
	Black shale	6	0	88	0
	Grey rock (very hard at 92-94 ft.)	95	6	183	6
	Bind	9	6	193	0
	Dark rock	4	0	197	0
	Dark bind	56	0	253	0
	Dark shale (Coal 2 in. about 281 ft.)	68	6	321	6
	Black shale	44	6	366	0

		Thickness Ft.	In.	Depth Ft.	In.
[Upper Meltham Coal]	Ganister (Coal 8 in. at top) ...	10	0	376	0
	Bind	16	6	392	6
[Huddersfield White Rock]	Grey rock	48	6	441	0
	Dark bind	60	0	501	0
	Grey rock	5	0	506	0
	Dark bind	3	6	509	6
	Blue rock	4	0	513	6
	Bind	0	6	514	0
	Black shale (Coal 5 in. at 588 ft.)	79	0	593	0
	Coal	1	2	594	2
	Grey rock	19	10	614	0
[Beacon Hill Flags]	Black rock	11	0	625	0

3. Rock Mills, Brockholes

A boring for water made at Joseph Sykes and Co.'s Mills, Brockholes. Partly communicated by Dr. T. W. Woodhead; see also *Quart. Journ. Geol. Soc.*, vol. lxxii, 1917, pp. 5 and 6, and above, p. 157. Height above O.D. 370 ft. Six-inch map, Yorkshire 260 S.E.

		Thickness Ft.	In.	Depth Ft.	In.
Alluvium	Sandy clay	8	0	8	0
	Water-bearing gravel	8	0	16	0
Shales with *Edestus*, etc. at 120 ft.	Soft shale (broken)	40	0	56	0
	Shale (broken) with sandy and ironstone bands	24	0	80	0
	Sandy shale (broken) with pyrites...	8	0	88	0
	Dark sandy shale (broken) ...	7	6	95	6
	Sandy shale (broken)	27	0	122	6
	Dark sandy shale (broken) crowded with *Modiola* at base	6	9	129	3
Upper Meltham Coal	Coal	0	3	129	6
	Sandy shale (broken)	12	6	142	0
Huddersfield White Rock	Dark sandstone		6	142	6
	Siliceous sandstone	1	6	144	0
	Conglomerate	3	0	147	0
	Micaceous shaly sandstone ...	13	3	160	3
	Coal and shale nodules (water)...	0	6	160	9
	Micaceous shaly sandstone ...	4	6	165	3

4. Skelmanthorpe

A boring for water alongside Skelmanthorpe Coke Ovens, Emley Moor Collieries (Messrs. Stringer & Co.). Made by Messrs. J. Thom and Co., Canal Works, Patricroft, Manchester. The site is alongside Baildon Dike, 400 yards due north of Skelmanthorpe railway station (L.M.S.). Height above O.D., 440 feet. Six-inch map, Yorkshire 261 S.E.

		Thickness Ft.	In.	Depth Ft.	In.
	Soil	2	6	2	6
	Broken ground	12	6	15	0
	Black shale	1	0	16	0
	Grey fireclay	11	0	27	0
	Black shale	1	0	28	0
	Grey fireclay	13	0	41	0
	White sandstone with thin layers of dark shale	4	0	45	0
	Grey shaly mudstone	44	0	89	0
	Dark grey shaly mudstone with ironstone bands	5	0	94	0
	Good fireclay with rootlets ...	3	0	97	0
	(Core lost)	5	0	102	0
	Bastard fireclay with ironstone balls	2	3	104	3
	Sandy shale with rootlets ...	4	9	109	0
	Band of ironstone	0	3	109	3
	Shaly mudstone	3	4	112	7
	Sandy bind or shale	12	9	125	4
	Fine black shaly mudstone ...	9	0	134	4
	Fireclay	1	0	135	4
	Fine black shaly mudstone ...	10	0	145	4
	(Core lost)	2	0	147	4
	Grey shaly rock	5	0	152	4
	Grey shaly mudstone	20	0	172	4
	Fine black shale	1	0	173	4
	Fireclay	3	6	176	10
	Bastard fireclay	3	0	179	10
	Sandy bind and mudstone with rootlets	7	0	186	10
	Shaly sandstone	1	6	188	4
	Sandy bind with ribs of rock ...	21	0	209	4
	Shaly mudstone with *Carbonicola communis* Davies and Trueman	2	6	211	10
	Soft black mudstone	0	3	212	1
	Black shale	0	3	212	4
Black Bed Coal	Coal	1	0	213	4
	Inferior coal	0	5	213	9
	Black shale with ribs of coal ...	1	11	215	8
	Blue sandy mudstone	1	6	217	2
	Fireclay with rootlets	0	2	217	4
	Blue sandy mudstone	4	8	222	0
	White rock with dark micaceous shale	10	0	232	0
	Dark mudstone	6	0	238	0
	Blue bind with ribs of rock with *Cordaites sp.*	14	0	252	0
	Soft mudstone with rootlets and ironstone bands	6	0	258	0
	Blue shale with rootlets ...	11	0	269	0
	White rock	2	0	271	0
	Blue bind	1	0	272	0
	Bastard rock with shale partings	1	0	273	0
	Blue shale	4	0	277	0
	Grey rock	4	0	281	0
	Blue shale	0	6	281	6
? Better Bed Coal	Coal (in washings : no core obtained)	3	0	284	6

	Thickness Ft.	In.	Depth Ft.	In.
Fireclay with rootlets	1	6	286	0
Blue shale with rock partings ...	24	6	310	6
Rock with dark micaceous shale bands	3	6	314	0
Fine hard grit rock	2	9	316	9
Rock with thin layers of blue micaceous shale	9	0	325	9
Blue bind with ribs of rock ...	5	0	330	9
Blue bind	7	0	337	9
Soft blue mudstone	3	6	341	3
Blue bind	15	6	356	9
Black shale	1	6	358	3
Coal and fireclay (in washings)...	1	4	359	7
Dark rock with bands of shale ...	5	0	364	7
Fine grit rock	0	3	364	10
Shale	1	6	366	4
Rock with shale partings ...	1	0	367	4
Shale	3	0	370	4
Hard strong blue shale	11	0	381	4
Blue shaly mudstone	5	9	387	1
Black shale	4	0	391	1
Fireclay	0	6	391	7
Black shale	1	6	393	1
Dark fireclay with rootlets ...	2	0	395	1
Grey fireclay with ironstone balls	3	0	398	1
Rock with ribs of shale	1	9	399	10
Black mudstone with ironstone balls	3	9	403	7
Dark grey mudstone	6	6	410	1
Strong blue shale	2	0	412	1
Soft shale	3	6	415	7
Hard gritstone with shale ...	7	8	423	3

For the above detailed section we are indebted to Mr. W. Lowe, M.I.M.E., of Messrs. Stringer and Co., Emley Moor Collieries, who periodically examined the cores.

A deep boring for water has also been made in Skelmanthorpe quite close to the above. It is on the premises of Messrs. Field and Bottrills at Greenside Mills. The site is almost alongside the L.M.S. Railway, 350 yards east of Skelmanthorpe railway station and 600 yards south of the Skelmanthorpe Coke Ovens boring. Height above O.D., 475 feet. Six-inch map, Yorkshire 261 S.E. The first sinking was made by Messrs. A. C. Potter and Co. of Grantham. It was carried to a depth of 375 feet and revealed a very similar section to that given above. It gave a fairly good supply of pure water. In 1928 the boring was considerably deepened by Messrs. R. A. Fitch and Co. of Mill Lane, Bradford. It was eventually carried through the Coal Measures into the Rough Rock and stopped at a depth of 1,218 feet. The Rough Rock yielded a very copious supply of pure and soft water. Although no detailed account of the strata passed through was available, we were able to examine the majority of the cores and the following is a generalized account of the section :—

		Thickness Ft.	In.	Depth Ft.	In.
Superficial	Clay and stones	14	0	14	0
	Shale and mudstone	77	0	91	0
	Alternations of sandy shale, flags and sandstone ribs ...	116	0	207	0
	Blue shale	30	0	237	0
	Shaly rock	11	6	248	6
	Soft shale	35	0	283	6
? Better Bed Coal	Coal	—	—	283	6
Elland Flags	Grey rock	20	6	304	0
	Shaly rock and sandstone ...	51	0	355	0
	Mainly shale	73	0	428	0
	Sandy shale with ribs of sandstone	12	0	440	0
	Bind	8	0	448	0
	Broken and jointed sandstone ...	18	0	466	0
	Mainly shale	134	0	600	0
	Very soft shale and mudstone ...	27	0	627	0
	Mainly shale	80	0	707	0
	Hard grey shaly sandstone ...	26	0	733	0
	Fireclay	1	0	734	0
	Grey rock	11	0	745	0
	Shale with thin layers of stone	125	0	870	0
Hard Bed Coal	Coal (thickness not given) ...	—	—	870	0
	Fireclay	4	0	874	0
	Shale	92	0	966	0
	Coal (thickness not given) ...	—	—	966	0
	Fireclay	2	0	968	0
	Shale	5	0	973	0
Soft Bed Coal	Coal	1	0	974	0
	Fireclay	3	0	977	0
Soft Bed Flags 95 ft.	Hard shale	29	0	1006	0
	Broken rock	66	0	1072	0
	Shale	72	0	1144	0
Pot Clay Coal	Coal (thickness not given) ...	—	—	1144	0
	Fireclay	3	0	1147	0
Rough Rock 71 ft. +	Shaly grit	14	0	1161	0
	Massive gritstone, jointed ...	57	0	1218	0

From the roof-shales of the coal at 1,144 ft. we obtained abundant impressions of goniatites and lamellibranchs, including *Gastrioceras subcrenatum* (Schloth.) and *Pterinopecten papyraceus* (J. Sow.). The roof-shales of the Halifax Hard Bed Coal at 870 ft. also yielded fossils, including *Gastrioceras listeri* (Martin), *Pterinopecten sp.*, *Posidonomya gibsoni* Salter, and *Lingula mytiloides* J. Sowerby.

APPENDIX II

List of the more important Quarries in Sheet 86 (Glossop)

Quarries marked with an asterisk (*) are standing.

6-inch map	Name of Quarry	Products	Geological horizon
	Yorkshire		
258 S.E.	Summer Hill Quarries,* Delph.	Sandstone	Holcombe Brook Grit (or Huddersfield White Rock).
259 S.W.	Nab End Quarries, Pule Hill, Marsden.	Gritstone and sandstone	Pule Hill Grit.
259 S.W.	Pule Edge Quarries, Marsden.	Paving setts and sandstone	Pule Hill Grit.
259 S.W.	Standedge Quarries,* west of Marsden.	Massive gritstone	Kinderscout Grit.
259 S.W.	Lurden Top Quarries.*	Gritstone for reservoir embankment work, etc.	Pule Hill Grit.
259 S.E.	Worlow Quarries, Marsden.	Sandstone	Pule Hill Grit.
259 S.E.	Netherley Quarry,* Marsden.	Sandstone	Pule Hill Grit.
259 S.E.	Scout Wood Quarry, Marsden.	Sandstone	Pule Hill Grit.
259 S.E.	Gate Head Quarries, Marsden.	Ganister rock	Beacon Hill Flags (Middle Grits).
259 S.E.	Shooters Nab Quarries.*	Gritstone and sandstone	Rough Rock.
259 S.E.	Deer Hill Quarry.*	Massive gritstone for reservoir embankment work	Rough Rock.
260 N.W.	Jubilee Quarries, Crosland Edge.	Sandstone	Rough Rock.
260 N.W.	New Warwick Quarries, South Crosland.	Sandstone	Rough Rock.
260 N.E.	Honley Ganister Quarries.	Ganister rock	Seat-earth of Halifax Hard Bed Coal; Lower Coal Measures.
260 N.E.	Mag Dale Quarries, Honley.	Sandstones	Rough Rock.
260 N.E.	Raw Gate Quarry, Farnley Tyas.	Flagstone	Elland Flags.
260 S.W.	Crosland Edge Quarries	Sandstone	Rough Rock.
260 S.W.	Warwick Quarries,* Crosland Edge.	Sandstone	Rough Rock.
260 S.W.	Royd Edge Quarries, Meltham.	Sandstones and flagstones	Huddersfield White Rock.
260 S.W.	Banister Edge Quarries, Meltham.	Ganister rock	Beacon Hill Flags.
260 S.W.	Honley Wood Quarries.*	Sandstone	Rough Rock.

6-inch map	Name of Quarry	Products	Geological horizon
	Yorkshire (*contd.*)		
260 S.W.	Woodside Quarries,* Meltham.	Sandstone	Huddersfield White Rock.
260 S.W.	Scotgate Head Quarries.	Building stone ; paving stone, etc.	Rough Rock.
260 S.W.	Royd Bridge Quarries,* Meltham.	Flagstone	Huddersfield White Rock.
260 S.W.	Slate Pits Wood Quarries, Meltham.	Flagstone	Rough Rock.
260 S.E.	Hagg Wood Quarries, Brockholes.	Building stone, and crushed for road material, etc.	Rough Rock.
260 S.E.	Brockholes Quarries.	Gritstone and sandstone.	Rough Rock.
260 S.E.	Sinking Wood Quarry.	Sandstone	Rough Rock.
260 S.E.	Lower Hagg Old Quarry,* Mytholm Bridge.	Sandstone	Huddersfield White Rock.
260 S.E.	Thurstonland Brickworks.*	Clays for brick-making	Shales above Elland Flags.
260 S.E.	Longley Quarry,* Longley Hill, Honley.	Flagstones	Elland Flags.
261 N.E.	Warburton Quarry,* Emley.	Sandstone	Emley Rock.
261 S.W.	Hartley Bank Quarries,* Thunderbridge.	Flagstone	Elland Flags.
261 S.W.	Woodhouse Field Quarries, Shelley.	Sandstone	Sandstone below Whinmoor Coal.
261 S.W.	Cumberworth Brickworks, Lower Cumberworth.	Clay for brick-making, tiles, etc.	Shales above Black Black Band Coal.
261 S.E.	Cliff Quarries, Clayton West.	Sandstone	Sandstone below Blocking Coal.
271 N.W.	Ladcastle Quarries.	Building stone, etc.	Kinderscout Grit.
271 N.W.	Nab End Quarries.	Building stone, setts, kerbs, rubble	Kinderscout Grit.
271 N.W.	Bakestone Delph.*	Bricks	Grindslow Shales.
271 N.W.	Running Hill Pits.*	Building stone in very large blocks	Kinderscout Grit.
271 N.W.	Greenfield Hall Quarries.	Building stone	Kinderscout Grit.
271 S.W.	Wickens Quarry.	Building stone, rubble, pitching	Kinderscout Grit.
272 N.W.	Kaye Stone Pits.	Flags, etc.	Huddersfield White Rock.
272 N.W.	Liphill Bank.*	Flags, etc.	Readycon Dean Series.

6-inch map	Name of Quarry	Products	Geological horizon
	Yorkshire (*contd.*)		
272 N.W.	Bingley.	Flags, etc.	Readycon Dean Series.
272 N.W.	Alison.	Flags, etc.	Readycon Dean Series.
272 N.W.	Bradshaw.	Flags, etc.	Heyden Rock.
272 N.W.	Woodhouse.	Building stone, sills, setts, kerbs, etc.	Heyden Rock.
272 N.W.	White Gate Edge.	Building stone, sills, setts, kerbs, etc.	Huddersfield White Rock.
272 N.E.	Victoria.*	Building stone, etc.	Readycon Dean Series.
272 N.E.	Dunsley Nook.	Building stone, sills, setts, kerbs, etc.	Huddersfield White Rock.
272 N.E.	Bank Head.	Building stone, sills, setts, kerbs, etc.	Huddersfield White Rock.
272 N.E.	Hill House.	Building stone, sills, setts, kerbs, etc.	Huddersfield White Rock.
272 N.E.	Paris.	Setts, kerbs, etc.	Rough Rock.
272 N.E.	Longley Edge.	Setts, kerbs, etc.	Rough Rock.
272 N.E.	Scar Hole.	Flags, rough walling	Greenmoor Rock.
272 S.W.	Heyden.*	Building stone, etc.	Heyden Rock.
272 S.E.	Catholes.	Building stone, etc.	Huddersfield White Rock.
272 S.E.	Hade Edge.	Building stone, etc.	Rough Rock.
272 S.E.	Magnum Bonum.*	Building stone, engine beds, setts, kerbs, etc.	Rough Rock and Rough Rock Flags.
272 S.E.	Lower Edge.	Building stone, silica rock, fireclay	Rough Rock and Rough Rock Flags.
272 S.E.	Snailsden.*	Building stone, etc.	Rough Rock and Rough Rock Flags.
273 N.W.	Lane End Appleton Sovereign Shepley	Building stone, flags, sills, setts, kerbs, monumental, etc.	Greenmoor Rock.
273 N.W.	Bird's Edge.*	Setts, kerbs, etc.	Penistone Flags.
273 N.W.	Delf Hills.*	Setts, kerbs, etc.	Penistone Flags.
273 N.E.	Pool Hill.	Walling, etc.	Parkgate Rock.
273 S.E.	Thurlstone.	Building stone, etc.	Greenmoor Rock.

6-inch map	Name of Quarry	Products	Geological horizon
	Yorkshire (*contd.*)		
280 N.W.	Greystone Edge.	Building stone, etc.	Heyden Rock.
281 N.E.	Race Common.	Building stone, etc.	Greenmoor Rock.
	Lancashire		
Lancs. 97 N.E.	High Moor.	Sandstone	Woodhead Hill Rock.
105 N.E.	Copley.*	Building stone	Pule Hill Grit.
	Cheshire		
Cheshire 3 N.E.	Buckton.	Roadstones, setts, concrete, kerbs	Kinderscout Grit.
3 N.E.	Cowburydale.*	Building stone	Kinderscout Grit.
3 S.E.	Roe Cross, Harrop Edge.	Building stone, setts, rubble, etc.	Kinderscout Grit.
4 N.W.	Brockholes.*	Building stone	Kinderscout Grit.
4 N.E.	Loftend Quarry.*	Building stone, kerbs, setts	Kinderscout Grit.
4 S.W. & S.E.	Tintwistle Bottoms.	Building stone for reservoir repairs	Kinderscout Grit.
	Derbyshire		
Derbyshire 2 S.E.	Mouselow.	Building stone, setts, etc.	Pule Hill Grit.
3 N.W.	Glossop Low.*	Roofing flags	Kinderscout Grit.
3 S.W.	Shire Hill.	Setts, kerbs and crushed for road material and sand	Kinderscout Grit.

APPENDIX III

List of Geological Survey Photographs

(New Series One-inch Sheet 86)

Copies of these photographs are deposited for public reference in the Library of the Geological Survey, London. Prints and lantern slides are supplied at a fixed tariff.

All numbers belong to Series A.

No. 3622.—Millstone Grits: massive Kinderscout Grit at Bilberry Reservoir.
,, 3623.—Millstone Grits: mouth of the Clough, Bilberry Reservoir. Typical Grit country.
,, 3624.—Millstone Grits and Recent: stream entering Bilberry Reservoir with shore lines in deposited mud, etc.
,, 3625.—Millstone Grits and Recent: same, looking upstream.
,, 3626.—Recent: meanders of stream in mud deposited at entrance to Bilberry Reservoir; polygonal sun-cracks on mud.
,, 3627.—Recent: same, looking downstream.
,, 3628.—Millstone Grits: Kinderscout Grit overlying shale and forming natural bridge in front of waterfall. Marsden Clough, Holmbridge (Plate IIb).
,, 3629.—Millstone Grits: the same natural bridge from above, showing method of formation.
,, 3630.—Millstone Grits: rock pool in Kinderscout Grit in bed of stream, just above and to show method of formation of the bridge.
,, 4543.—Millstone Grits: band of bullions with goniatites (mut. marine band) in shale. Stream cliff in Heyden Clough.
,, 4544.—Pleistocene and Recent: wasting peat on Holme Moss.
,, 4545.—Millstone Grits: landslip at Holme Woods.
,, 4546.—Millstone Grits: exposures in Ramsden Clough (Plate IIIa).
,, 4547.—Millstone Grits: quarry in Huddersfield White Rock, White Gate Edge, Holmbridge.
,, 4548.—Millstone Grits and Lower Coal Measures: Coal Measures shales faulted against Rough Rock, Pickles Clough, Hepworth.
,, 4549.—Lower Coal Measures: escarpment capped by Greenmoor Rock, Cheese Gate Nab, Hepworth (Plate IVa).
,, 4550.—Millstone Grits: steeply bedded Rough Rock, Cook's Study.
,, 4551.—Millstone Grits: Dolly Folly waterfall over Huddersfield White Rock faulted against shale, Meltham.
,, 4552.—Millstone Grits: ganister overlain by shales with mut. γ marine band, Banister Edge, Meltham.
,, 4553.—Millstone Grits and Lower Coal Measures: junction of Coal Measures and Rough Rock, railway-cutting, Brockholes.
,, 4554.—Lower Coal Measures: succession of sandstone escarpments, Hall Ing, Honley.
,, 4555.—Millstone Grits: outlier of Rough Rock Flags, Meltham Cop.
,, 4556.—Millstone Grits: typical clough crossed by ancient pack-horse bridge, Redbrook Clough, Marsden.
,, 4557.—Millstone Grits: same, showing built-up track to bridge.
,, 4558.—Millstone Grits: Stonepit Clough and Standedge Moors, Marsden.
,, 4559.—Millstone Grits: outlier of Pule Hill Grit, shales with marine bands below, Pule Hill, Marsden (Plate IIIb).

No. 4560.—Millstone Grits: outlier of Rough Rock, slopes of Middle Grits and surface of Kinderscout Grit, Butterly Reservoir, Marsden.
,, 4561.—Millstone Grits and Recent: clough entering Butterly Reservoir; deltaic deposit with shore lines, Butterly, Marsden.
,, 4562.—Millstone Grits and Recent: same, looking downstream; Kinderscout Grit crags in distance.
,, 4563.—Millstone Grits and Recent: same, with stream flowing through delta fan.
,, 4564.—Millstone Grits: waterfall over Kinderscout Grit underlain by shale, Butterly Clough, Marsden.
,, 4565.—Millstone Grits: escarpment with crags of Kinderscout Grit, Alderman's Rocks, Greenfield.
,, 4566.—Millstone Grits: same.
,, 4567.—Millstone Grits: same, showing joints.
,, 4568. Millstone Grits: landslip of Kinderscout Grit on underlying shales, Sail Bark Rocks, Greenfield.
,, 4569.—Millstone Grits: gorge cut through Kinderscout Grit and underlying beds, Greenfield Brook.
,, 4570.—Millstone Grits: crags of well-jointed Kinderscout Grit, Raven Stones, Greenfield.
,, 4571.—Millstone Grits: weathered stacks of Kinderscout Grit, Raven Stones, Greenfield (see frontispiece).
,, 4572.—Millstone Grits: deep gorge in Kinderscout Grit, from Raven Stones, Greenfield.
,, 4573.—Glacial: sand-pit in glacial sands, Melandra Castle, Brookfield.
,, 4574.—Glacial: same, nearer view showing current-bedding.
,, 4575.—Millstone Grits: escarpment and dip-slope, Peak Naze.
,, 4576.—Millstone Grits: quarry in Kinderscout Grit with strong vertical joints, Tintwistle Knarr, Longdendale.
,, 4577.—Recent: parallel sun-cracks in peaty mud deposited in Torside Reservoir, Longdendale.
,, 4578.—Recent: sun-cracks in mud, approaching polygonal form, Torside Reservoir, Longdendale.
,, 4579.—Recent: strand lines in deltaic deposit, formed by successive lowerings of water-level, Woodhead Reservoir, Longdendale.
,, 4580.—Millstone Grits: cascade over massive Kinderscout Grit, Oakenclough Brook, Crowden.
,, 4581.—Millstone Grits: quarry in Kinderscout Grit, showing wedge-bedding, Loftend, Crowden.
,, 4582.—Millstone Grits: same quarry showing shatter-belt due to faulting.
,, 4583.—Millstone Grits: ferruginous concretion ('mare's ball') in Kinderscout Grit, same quarry.
,, 4584.—Millstone Grits: crag of Kinderscout Grit showing curious markings on weathered surface, Clough Edge, Torside Clough, Longdendale.
,, 4708.—Millstone Grits: quarry in Rough Rock overlain by 'Head,' Broadbottom.
,, 4709.—Millstone Grits: river cliff of Rough Rock, Rough Rock Flags and underlying shales: River Etherow, Broadbottom.
,, 4710.—Millstone Grits: gorge in Rough Rock of River Etherow, Broadbottom.
,, 4711.—Millstone Grits: cliffs of Kinderscout Grit forming edge of gorge of Crowden Great Brook, Crowden.
,, 4712.—Millstone Grits: nearer view of same.
,, 4713.—Millstone Grits and Recent: alluvial boulders in gorge of Near Black Clough, Woodhead.
,, 4714.—Millstone Grits: gorge in basal Kinderscout Grit, at junction of Three Black Cloughs, Woodhead.
,, 4715.—Millstone Grits: same, showing topmost bed of Grindslow Shales beneath Kinderscout Grit (Plate IIA).

No. 4716.—Millstone Grits: The Three Black Cloughs, Woodhead.
,, 4717.—Millstone Grits and Recent: Kinderscout Grit in gorge cut rapidly by a stream which has captured the upper waters of a parallel stream. Far Black Clough, Woodhead.
,, 4718.—Millstone Grits: cliffs of Kinderscout Grit in same gorge.
,, 4719.—Millstone Grits: same gorge higher upstream.
,, 4720.—Millstone Grits: crags of Kinderscout Grit terminated by fault, Grinah Stones, Woodhead.
,, 4721.—Millstone Grits and ? Glacial: crag of Kinderscout Grit with detached blocks which have slipped downhill, possibly on a snow-slope. Grinah Stones, Woodhead.
,, 4722.—Millstone Grits: crag of Kinderscout Grit, Grinah Stones, Woodhead.
,, 4723.—Millstone Grits: weathered blocks of grit on moor covered with bilberry, Barrow Stones, Woodhead.
,, 4724.—Millstone Grits: curious weathering of blocks of Kinderscout Grit, Barrow Stones, Woodhead.
,, 4725.—Millstone Grits: same.
,, 4726.—Millstone Grits: detail of same.
,, 4727.—Millstone Grits: same, showing detached blocks surrounded by bilberry and crowberry.
,, 4728.—Millstone Grits: pot-holes in same blocks.
,, 4729.—Millstone Grits: detail of a pot-hole in same.
,, 4730.—Millstone Grits: weathered crags of Kinderscout Grit, Rocking Stones, Howden Moors.
,, 4731.—Millstone Grits: another view of same.
,, 4732.—Millstone Grits: another view of same.
,, 4733.—Millstone Grits: same, showing bedding and jointing.
,, 4734.—Millstone Grits: same, showing undercutting by wind erosion.
,, 4735.—Millstone Grits: same.
,, 4736.—Millstone Grits: distant view of Derwent valley and plateaux of Shale Grit, from Rocking Stones, Howden Moors.
,, 4737.—Millstone Grits: plateau of Shale Grit backed by escarpments of Kinderscout Grit, Cut Gate Moors.
,, 4738.—Millstone Grits: grit escarpment over shales in Kinderscout Grit; heather on well-drained peat. Howden Moors.
,, 4739.—Millstone Grits: weathering of thinly bedded Kinderscout Grit crag, Howden Moors.
,, 4740.—Millstone Grits: landslip in Kinderscout Grit holding up deep pond. Mickleden Pond, Langsett.
,, 4741.—Millstone Grits: another view of same.
,, 4742.—Millstone Grits: landslips on slope of Bradshaw Hill, Langsett.
,, 4743.—Millstone Grits: cliff of Rough Rock Flags and Shale faulted against Huddersfield White Rock, Little Don valley west of Langsett.
,, 4744.—Millstone Grits: shales above mut. γ marine band exposed in stream section, south of Langsett Reservoir.
,, 4745.—Millstone Grits: disturbed shales as above.
,, 4746.—Millstone Grits: nearer view of same shales.
,, 4747.—Millstone Grits: shales with mut. γ marine band disturbed by fault, south of Langsett Reservoir.
,, 4748.—Millstone Grits: nearer view of same.
,, 4749.—Lower Coal Measures: successive sandstone escarpments, seen from Midhope Moors, Langsett Reservoir.
,, 4750.—Lower Coal Measures: successive sandstone escarpments, east of Langsett.
,, 4751.—Lower Coal Measures: same escarpments from Rough Rock platform between Hazlehead and Flouch Inn.
,, 4752.—Millstone Grits: view up Ewden Beck valley.
,, 4753.—Millstone Grits: landslips from base of Huddersfield White Rock, Canyards Hills, near Broomhead.

No. 4754.—Millstone Grits : escarpment of Huddersfield White Rock with landslips, near Wightwizzle.
,, 4756.—Millstone Grits : view of Ewden Beck valley and Broomhead Reservoir.
,, 4757.—Millstone Grits : another view of same.
,, 4758.—Lower Coal Measures : coal and marine band above Rough Rock, Bull Pit near Langsett.
,, 4759.—Lower Coal Measures : Penistone Flags in bank of River Don, which is crossed by pack-horse bridge, below Penistone Station (Plate IVB).
,, 4760.—Millstone Grits : Rough Rock with highly inclined bedding. Cook's Study, Holmfirth.
,, 4761.—Millstone Grits : another view of same.
,, 4763.—Millstone Grits : view down Ramsden Clough, cut in Middle Grits; plateau of Huddersfield White Rock in distance.
,, 4764.—Millstone Grits : view down Ruddle Clough, cut in Middle Grits and Shales, into Ramsden Clough.
,, 4765.—Millstone Grits : Ramsden Rocks, escarpment of Huddersfield White Rock, Ramsden Clough.
,, 4766.—Millstone Grits : nearer view of same crags.
,, 4767.—Millstone Grits : Lindley's Quarry, Magnum Bonum, south of Holmfirth, showing Rough Rock, coal seam, fireclay and Rough Rock Flags.
,, 4768.—Millstone Grits : another view of same.
,, 4769.—Millstone Grits : Rough Rock resting on a coal seam; same quarry.
,, 4770.—Millstone Grits : nearer view of same.
,, 4771.—Millstone Grits : same quarry showing Rough Rock, coal, fireclay and Flags.
,, 4772.—Millstone Grits : spheroidal weathering in Rough Rock; same quarry.
,, 4773.—Millstone Grits : highly inclined beds of sandstone, Winscar Quarries, south of Holmfirth.
,, 4774.—Millstone Grits : Wagstaff's Quarry in flagstone used for roofing, Windledon, Dunford Bridge.
,, 4775.—Millstone Grits : shales with mut. γ marine band resting on flags; same quarry.
,, 4776.—Millstone Grits : another view of same.
,, 4777.—Millstone Grits : Normanton's Quarry in Rough Rock freestone, Scotgate, Honley.
,, 4778.—Millstone Grits : same beds in Thornton's Quarry, Scotgate.
,, 4779.—Millstone Grits : garden ornaments, etc. cut from same rock.
,, 4780.—Millstone Grits : another group of same.
,, 4781.—Lower Coal Measures : Grenoside Rock and Elland Flagstone; gorge of the Burton Brook, Thunder Bridge, Shelley.
,, 4782.—Lower Coal Measures : Hampson's Quarry in Greenmoor Rock, Lane Head, near Shepley.
,, 4783.—Lower Coal Measures : Greenmoor Rock and overlying mudstones, same quarry.
,, 4784.—Lower Coal Measures : Greenmoor Rock in Smith, Heywood's Quarry, Lane Head.
,, 4785.—Lower Coal Measures : Greenmoor Rock in Lindley's Quarry, Lane Head.
,, 4786.—Lower Coal Measures : another view of same.

INDEX

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*Sheet 82 S.W.—Chesterfield, Matlock, Clay Cross (1866)	5 3	—
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Sheet 87 S.E.—Doncaster (1876)	6 9	—
Sheet 92 N.W.—Settle, Malham, Gargrave (1892)	9 9	9 9
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